40110719

SUPERFUND RECORDS

D ... MO ...
108

no confident ... for ...

6-17-85

Facility name Jasper County Mining District

Location Jasper County, Missouri

EPA Region VII

Person(s) in charge of the facility

Name of Reviewer Glenn M Curtis Date 6/17/85

General description of the facility

(For example landfill surface impoundment, pile container types of hazardous substances location of the facility contamination route of major concern types of information needed for rating agency action etc.)

The site encompasses approximately 12 square miles of mining activity i e pits, shafts, tailing piles The area was mined between early 1800 s to 1950 for lead, zinc and cadmium. Tailing piles, pits and mine shafts threaten to contaminate area groundwater and surface water resources.

Scores S_M = 43 31 (S_{gw} = 42 86 S_{sw} = 61 45 S_a = 0)

S_{FE} =

S_{DC} =

FIGURE 1
HRS COVER SHEET

Ground Water Route Work Sheet					
Rating Factor	**Assigned Value (Circle One)**	**Multiplier**	**Score**	**Max Score**	**Ref (Section)**
1 Observed Release	0 45	1	45	45	3 1
If observed release is given a score of 45 proceed to line 4 If observed release is given a score of 0 proceed to line 2					
2 Route Characteristics					3 2
Depth to Aquifer of Concern	0 1 2 3	2	6	6	
Net Precipitation	0 1 2 3	1	3	3	
Permeability of the Unsaturated Zone	0 1 2 3	1	3	3	
Physical State	0 1 2 3	1	1	3	
	Total Route Characteristics Score			15	
3 Containment	0 1 2 3	1		3	3 3
4 Waste Characteristics					3 4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					3 5
Ground Water Use	0 1 2 3	3	9	9	
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	12	40	
	Total Targets Score		21	49	
6 If line 1 is 45 multiply 1 x 4 x 5 45x26x21=24570 If line 1 is 0 multiply 2 x 3 x 4 x 5				57 330	
7 Divide line 6 by 57 330 and multiply by 100			S_{gw} = 42 8571		

FIGURE 2
GROUND WATER ROUTE WORK SHEET

29
-1

45x20x21 18900 = 5497
1000 5 - 5

Surface Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max Score	Ref (Section)
1 Observed Release	0 45	1		45	4 1
If observed release is given a value of 45 proceed to line 4 If observed release is given a value of 0 proceed to line 2.					
2 Route Characteristics					4 2
Facility Slope and Intervening Terrain	0 1 2 3	1	3	3	
1 yr 24-hr Rainfall	0 1 2 3	1	3	3	
Distance to Nearest Surface Water	0 1 2 3	2	6	6	
Physical State	0 1 2 3	1	1	3	
	Total Route Characteristics Score		13	15	
3 Containment	0 1 2 3	1	3	3	4 3
4 Waste Characteristics					4 4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					4 5
Surface Water Use	0 1 2 3	3	9	9	
Distance to a Sensitive Environment	0 1 2 3	2	0	6	
Population Served/Distance to Water Intake Downstream	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	30	40	
	Total Targets Score		39	55	
6 If line 1 is 45 multiply 1 x 4 x 5 If line 1 is 0 multiply 2 x 3 x 4 x 5 13x3x26x39 3			37546	64 350	
7 Divide line 6 by 64 350 and multiply by 100	S_{sw} = 61 4546				

FIGURE 7
SURFACE WATER ROUTE WORK SHEET

13 x 3 x 20 x 39

4727

22347

No observed release / Not Applicable

Air Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max Score	Ref (Section)
1 Observed Release	0 45	1		45	5 1
Date and Location					
Sampling Protocol					
If line 1 is 0 the S_a = 0 Enter on line 5 If line 1 is 45 then proceed to line 2					
2 Waste Characteristics					5 2
Reactivity and Incompatibility	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
	Total Waste Characteristics Score			20	
3 Targets					5 3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
	Total Targets Score			39	
4 Multiply 1 x 2 x 3				35 100	
5 Divide line 4 by 35 100 and multiply by 100	S_a =				

FIGURE 9
AIR ROUTE WORK SHEET

0

	s	s^2
Groundwater Route Score (S_{gw})	42 8571	1836 731
Surface Water Route Score (S_{sw})	61 4546	3776 668
Air Route Score (S_a)	—	
$S_{gw}^2 + S_{sw}^2 + S_a^2$		5613 399
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$		74 923
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2} / 1\ 73 = S_M =$		43 31

FIGURE 10
WORKSHEET FOR COMPUTING S_M

Fire and Explosion Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max Score	Ref (Section)
1 Containment	1 3	1		3	7 1
2 Waste Characteristics					7 2
Direct Evidence	0 3	1		3	
Ignitability	0 1 2 3	1		3	
Reactivity	0 1 2 3	1		3	
Incompatibility	0 1 2 3	1		3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
	Total Waste Characteristics Score			20	
3 Targets					7 3
Distance to Nearest Population	0 1 2 3 4 5	1		5	
Distance to Nearest Building	0 1 2 3	1		3	
Distance to Sensitive Environment	0 1 2 3	1		3	
Land Use	0 1 2 3	1		3	
Population Within 2 Mile Radius	0 1 2 3 4 5	1		5	
Buildings Within 2 Mile Radius	0 1 2 3 4 5	1		5	
	Total Targets Score			24	
4 Multiply 1 x 2 x 3				1 440	
5 Divide line 4 by 1 440 and multiply by 100	S_{FE} =				

FIGURE 11
FIRE AND EXPLOSION WORK SHEET

Direct Contact Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max Score	Ref (Section)
1 Observed Incident	0 45	1		45	8 1
If line 1 is 45 proceed to line 4 If line 1 is 0 proceed to line 2					
2 Accessibility	0 1 2 3	1		3	8.2
3 Containment	0 15	1		15	8 3
4 Waste Characteristics Toxicity	0 1 2 3	5		15	8 4
5 Targets					8 5
Population Within a 1-Mile Radius	0 1 2 3 4 5	4		20	
Distance to a Critical Habitat	0 1 2 3	4		12	
Total Targets Score				32	
6 If line 1 is 45 multiply 1 x 4 x 5 If line 1 is 0 multiply 2 x 3 x 4 x 5				21 600	
7 Divide line 6 by 21 600 and multiply by 100			S_{DC} =		

FIGURE 12
DIRECT CONTACT WORK SHEET

June 28, 1982

DOCUMENTATION RECORDS
FOR
HAZARD RANKING SYSTEM

INSTRUCTIONS The purpose of these records is to provide a convenient way to prepare an auditable record of the data and documentation used to apply the Hazard Ranking System to a given facility As briefly as possible summarize the information you used to assign the score for each factor (e g , "Waste quantity = 4,230 drums plus 800 cubic yards of sludges") The source of information should be provided for each entry and should be a bibliographic-type reference that will make the document used for a given data point easier to find Include the location of the document and consider appending a copy of the relevant page(s) for ease in review

FACILITY NAME Jasper County Mining District

LOCATION Jasper County, Missouri

Attachments

WESTON DESIGNERS CONSULTANTS

BY GMC DATE 6/17 DIV ______ SHEET 1 OF ______
CHKD BY ______ DATE ______ DEPT ______ W O NO ______
PROJECT Jasper County Mining District
SUBJECT Groundwater - Observed Release

Rationale:

Mine tailing piles and other wastes were routinely piled during previous mining activity near shaft openings and pits Refer to Reference #2 pages 20-23, 25-33, 36, 38, 39, 46-47, 49-50, 52, 55, 57, 66, 68 75-76, 78, 86 Tailing pile runoff high in heavy metals (Reference #1 page 17-18, 23) will obviously enter the adjacent shafts and/or mine pits contaminating the area groundwater

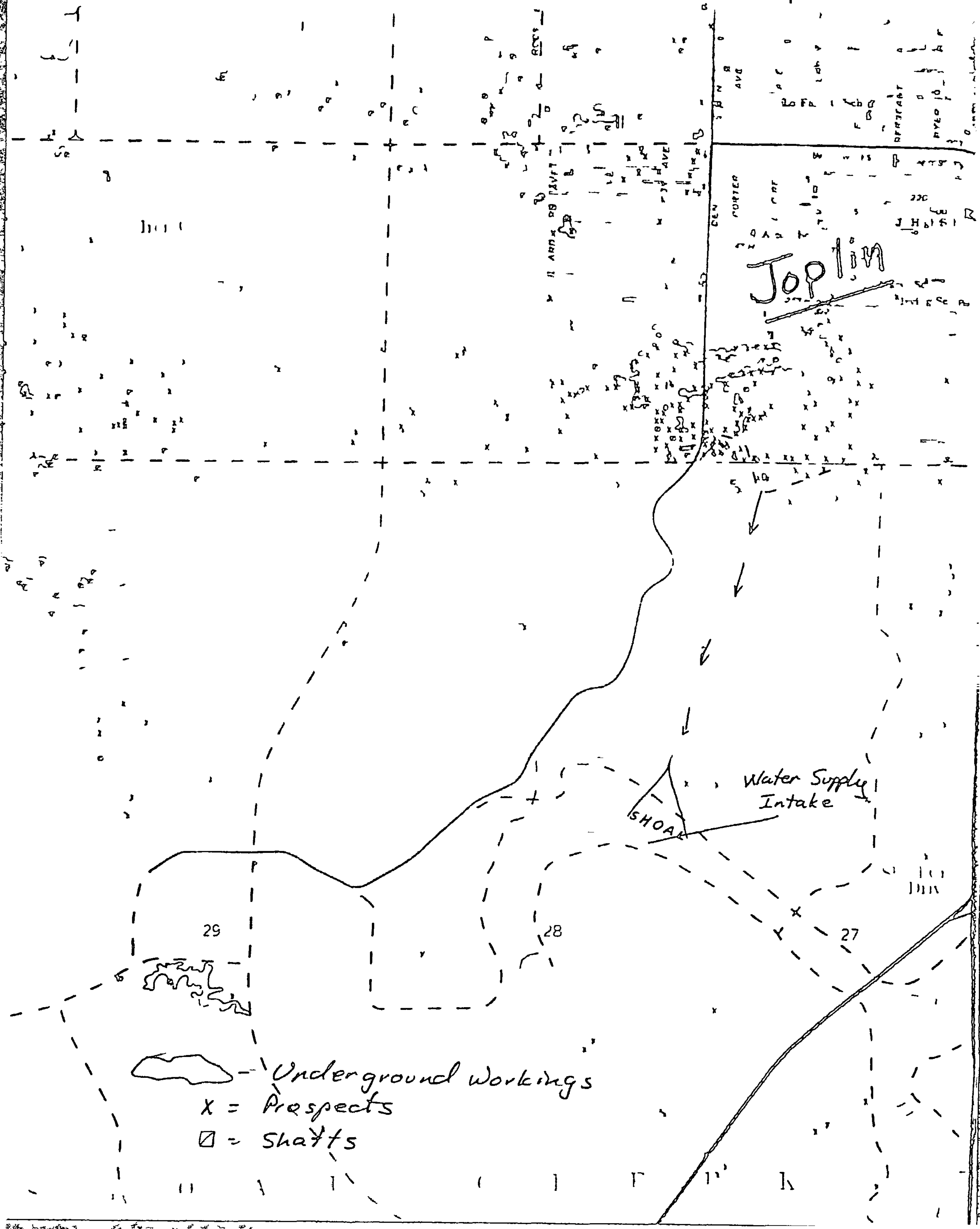
Attachments

WESTON DESIGNERS CONSULTANTS

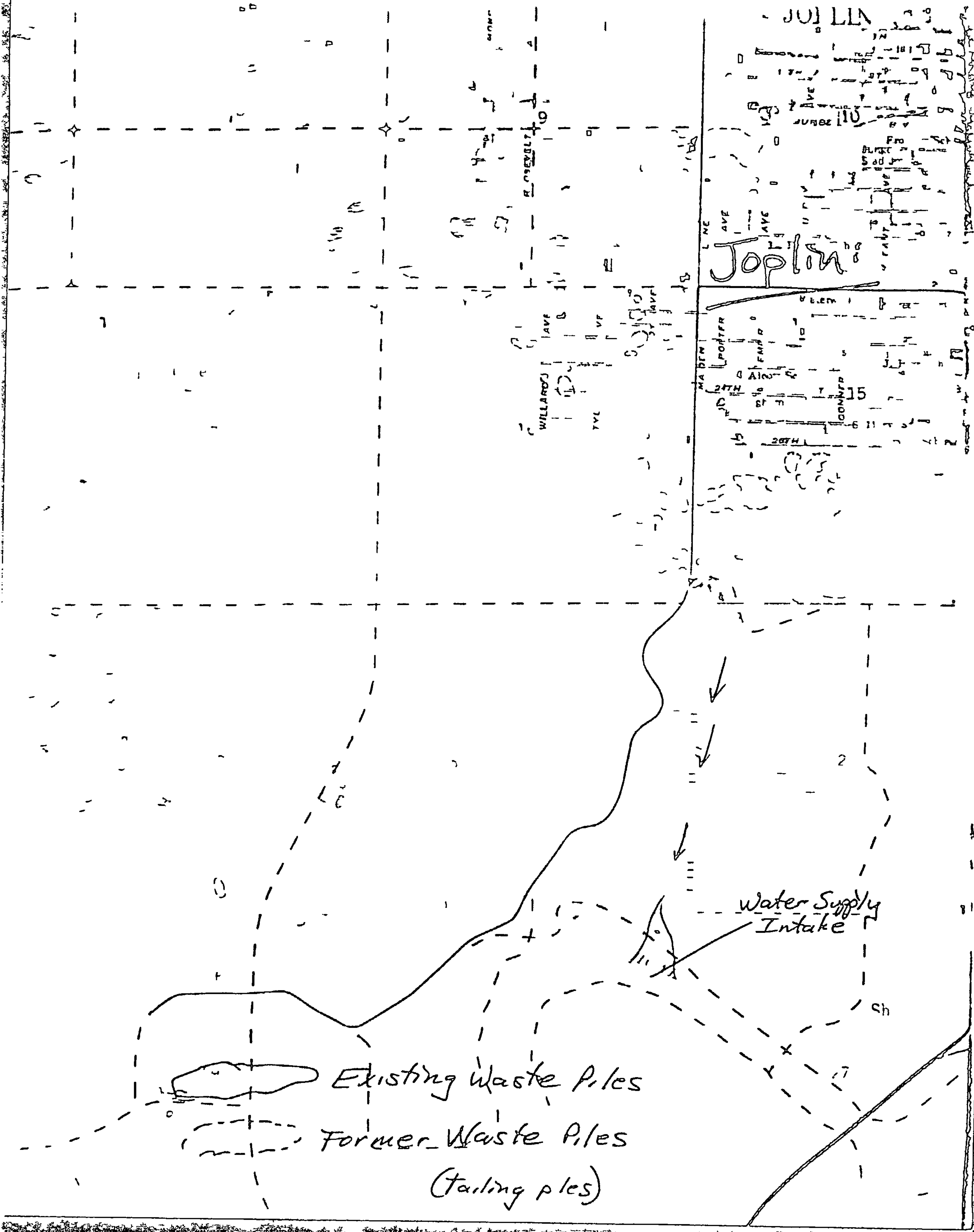
BY GMC DATE 6/17 DIV ______ SHEET 2 OF ______
CHKD BY ______ DATE ______ DEPT ______ W O NO ______
PROJECT Jasper County Mining District
SUBJECT Surface Water

Documents supporting release of contaminated mine tailing runoff to area surface waters is presented in Referene #1 pages 13, 15, 17-21, 23, 34 Contaminated runoff from waste and tailing piles adjacent or very near waterways will constitute a source of contamination of the exposed surface waters

Attachment pg 3



Attachment pg 4



Reference # 1

EFFECTS OF ABANDONED LEAD AND ZINC MINES AND TAILINGS PILES ON WATER QUALITY IN THE JOPLIN AREA, MISSOURI

by James H Barks

U S GEOLOGICAL SURVEY

Water-Resources Investigations 77-75

Prepared in cooperation with

the Ozark Gateway Council of Governments

August 1977

REFERENCES CITED

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Skelton John 1977, Streamflow characteristics of the Joplin area Missouri U S Geol Survey Open-file Report 77-605, 44 p

U S Public Health Service, 1962, Drinking water standards, revised U S Public Health Service Pub 956, 61 p

Effects of Abandoned Lead and Zinc Mines and Tailings Piles on Water Quality in the Joplin Area, Missouri

By James H Barks

ABSTRACT

Dissolved zinc concentrations averaged 9,400 µg/L (micrograms per liter) in water from abandoned lead and zinc mines, some of which discharge at the surface Contamination of the shallow aquifer (cherty limestones) by the highly mineralized mine water is limited to the immediate mining area The quality of water in the deep aquifer (cherty dolomites and sandstone) is generally excellent

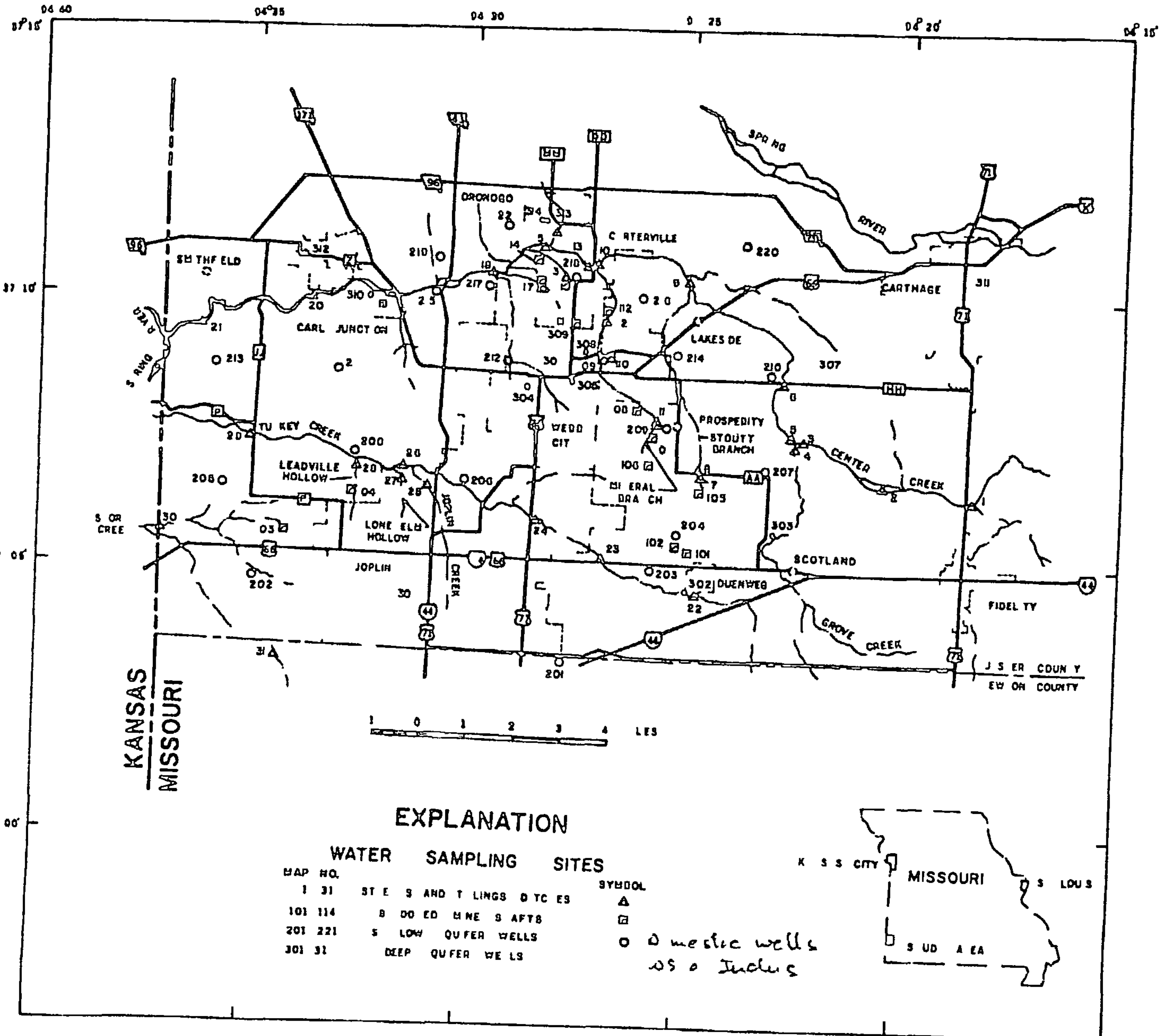
Dissolved zinc concentrations averaged 16,000 µg/L in runoff from tailings areas However, during a summer storm, runoff from a 7-acre tailings area contained maximum dissolved zinc, lead, and cadmium concentrations of 200,000, 400, and 1,400 µg/L, respectively

Mine-water discharges increase dissolved zinc concentrations in receiving streams from a background of about 40 µg/L to about 500 µg/L during periods of low flow The higher concentrations are sustained during high flow by runoff from the tailings areas Deposition of tailings on stream bottoms increases zinc concentrations in bottom material from a background of about 100 µg/g (micrograms per gram) to about 2 500 µg/g and increases lead concentrations in bottom material from about 20 µg/g to about 450 µg/g

INTRODUCTION

Commercial development of the mineral resources of southwestern Missouri began about 1850 and spread into southeastern Kansas and northeastern Oklahoma, forming the Tri-State District with Joplin as the urban center The value of the Tri-State mineral production from 1850 to 1950 exceeded one billion dollars, and until 1945 ~~the region was the world's leading producer of lead and zinc concentrates~~, accounting for one-half of the zinc and one-tenth of the lead produced in the United States (Gibson, 1972) By 1950 most of the rich ores had been extracted, and mining and milling operations declined during the 1950's and ceased in the 1960's

Throughout the mining era ground water remained a problem to the district The natural level of the water table was usually higher than the mines and flooding of the mines was controlled only by constant pumping When pumpage declined in the 1950's and 1960's the mine drifts and shafts filled with water



F gu e 1 Map of the Joplin a ea Missou i showi g associated ate sa pli g tes

Water temperature, specific conductance, pH, alkalinity, and dissolved oxygen were determined in the field Water temperature was measured with a mercury thermometer to the nearest 0 5°C (degrees Celsius) Specific conductance was measured using a portable conductivity meter with temperature compensation designed to express readings in µmhos/cm at 25°C (micromhos per centimeter at 25 degrees Celsius) The potentiometric method was used to measure both the pH and alkalinity The inflection points in the titration for alkalinity with 0 01639 normal sulfuric acid were 8 3 and 4 5 for bicarbonate The azide modification of the Winkler method was used for dissolved oxygen determinations The only departure from these methods was the determination of temperature specific conductance, dissolved oxygen, and pH profiles in mine shafts using an electronic instrument calibrated according to the manufacturer's instructions

GROUND WATER

~~Important aquifers in the area include the shallow aquifer in cherty limestones of Mississippian age and the deep aquifer in cherty dolomites and sandstone of Ordovician and Cambrian age~~ The shallow and deep aquifers are separated by relatively impermeable silty limestones and shale of Mississippian and Devonian age A generalized section of the geologic formations and their hydrologic properties is given in table 1, in the back of the report

The shallow aquifer reaches the surface at places and extends as deep as 500 ft (feet) Brecciated areas generally are highly permeable while surrounding areas of dense limestone have low permeabilities Mineral deposits in the brecciated areas were mined at depths from 100 to 250 ft The abandoned mines contain large volumes of highly mineralized water

A potentiometric map of the shallow aquifer (fig 2) was prepared from water levels that were measured in approximately 200 shallow wells and mine shafts in September and early October 1976 during a period of little precipitation and low streamflow The map shows the slope and direction of ground-water movement Water levels represent the water table except for the few wells and mines that have water under artesian pressure The water table is usually close to land surface near main streams and from 25 to 100 ft below land surface away from main streams Center and Turkey Creeks are in hydraulic connection with the shallow aquifer and generally act as drains Hydrologic divides generally correspond to topographic divides and movement of the ground water is from the divide areas to the streams Regional movement of the water in the shallow aquifer is toward the west

A comparison of the September-October 1976 and June 1966 (Feder and others, 1969 p 28) potentiometric maps shows that except for the area north of Duenweg, the altitude of the water table and movement of the ground water is unchanged In 1966 heavy pumping in the area north of Duenweg formed a cone od depression and altered the ground-water flow pattern causing water to flow into the cone to replace water that had been pumped out Most of the pumpage stopped soon after the 1966 water-level measurements were made The 1976 measurements show a recovery of about 100 to 150 ft in water-table altitude in the Duenweg area Consequently, the 1976 map does not show a depression in the water table north of Duenweg

The deep aquifer is reached at a minimum depth of about 300 ft and extends as deep as 1,800 ft Water in the deep aquifer is under artesian pressure, but water-level measurements indicate that the potentiometric surface of the deep aquifer is below that of the shallow aquifer (Feder and others, 1969, p 12) This relationship favors downward seepage of water, and where faults, fracture openings, and wells connect the aquifers, water can leak directly from the shallow aquifer to the deep aquifer Where the aquifers are separated by the Northview Formation, the Chattanooga Shale, or both, these shales act as confining beds permitting little water movement

In 1976 water samples were collected from 14 mines, 21 shallow wells, and 14 deep wells Results of analyses of these samples are shown in tables 2 3, and 4, respectively, in the back of the report The data are summarized in table 5 and figure 3 and discussed under the topics, "Mines," "Shallow wells," and "Deep wells "

Mines

Dissolved-solids concentrations in water from mine drifts are generally greater than 1,000 mg/L (milligrams per liter) In ground-water recharge areas (higher altitudes away from main streams) downward water movement prevents water in the drifts from circulating up into the mine shafts, and water in these shafts contain less than 500 mg/L dissolved solids Conversely, in ground-water discharge areas (lower altitudes near main streams or water under artesian pressure) upward water movement causes water in the drifts to circulate up through the mine shafts This phenomenon is illustrated by the sketch in figure 4 and by specific conductance, pH, temperature, and dissolved oxygen profiles (fig 5) that represent average characteristics for seven mines (map nos 101, 102 103 106, 107, 108, and 113) in recharge areas and for three mines (map nos 104, 112, and 114) in discharge areas Average depth to the water surface was 35 ft in recharge areas and 1 ft in discharge areas The relation between dissolved solids (DS) and specific conductance (SC) for water in the drifts and shafts is DS=(0 99XSC)-121, the standard error of estimate is 49 mg/L DS In table 2, in the back of the report, those analyses with dissolved-solids concentrations less than 500 mg/L are for water collected from shafts in ground-water recharge areas Those with dissolved-solids concentrations greater than 900 mg/L are for water collected from drifts in the recharge areas or from shafts in ground-water discharge areas All of the analyses were used to compute values shown for mines in table 5 and figure 3

Water in limestone rocks is usually a calcium bicarbonate type, but water in the abandoned mines is a calcium sulfate type (fig 3), reflecting the sulfide mineralization

Average concentrations of dissolved iron, manganese, cadmium, and zinc in the mine water (table 5) exceed concentrations of 300, 50, 10, and 5,000 µg/L, respectively, recommended as drinking water standards (U S Public Health Service 1962) Concentrations of other metals in the mine water are

Table 5.--Average values of characteristics and dissolved constituents of water from mines, shallow wells, and deep wells

Characteristic or constituent	Average value		
	Mines	Shallow wells	Deep wells
Silica (SiO_2), in mg/L-------	12	9.2	9.4
Calcium (Ca), in mg/L--------	264	89	44
Magnesium (Mg), in mg/L------	7.6	7.7	16
Sodium (Na), in mg/L---------	5.7	8.1	8.1
Potassium (K), in mg/L-------	1.4	1.5	2.2
Bicarbonate (HCO_3), in mg/L--	140	214	195
Sulfate (SO_4), in mg/L-------	580	72	28
Chloride (Cl), in mg/L-------	2.9	7.4	6.8
Fluoride (F), in mg/L--------	0.6	0.2	0.2
Dissolved solids, in mg/L----	1,030	327	207
Hardness as $CaCO_3$, in mg/L---	690	250	180
Alkalinity as $CaCO_3$, in mg/L--	115	176	160
Specific conductance, in µmhos/cm at 25°C-----------	1,160	522	373
pH, in units----------------	6.9	6.9	7.4
Temperature, in °C-----------	15.0	17.5	18.5
Aluminum (Al), in µg/L-------	10	20	10
Cadmium (Cd), in µg/L--------	25	4	0
Chromium (Cr), in µg/L-------	0	---------	---------
Cobalt (Co), in µg/L---------	5	---------	---------
Copper (Cu), in µg/L---------	2	2	1
Iron (Fe), in µg/L-----------	5,100	350	30
Lead (Pb), in µg/L-----------	10	10	6
Manganese (Mn), in µg/L------	180	60	10
Mercury (Hg), in µg/L--------	0.5	---------	---------
Nickel (Ni), in µg/L---------	46	7	0
Silver (Ag), in µg/L---------	0	---------	---------
Zinc (Zn), in µg/L-----------	9,400	1,100	70

well below the drinking water standards. High concentrations of zinc in the mine water are particularly significant because zinc is highly toxic to aquatic animals and some of the mine water reaches the main streams in the area as discussed later in the report.

Shallow Wells

Many of the 21 shallow wells that were sampled are located between the flooded mines and Center and Turkey Creeks. Average depth of the wells is 243 ft, which is a little deeper than most mines in the area.

Water in the shallow wells is generally a calcium bicarbonate type (fig. 3). Only four of the wells (map nos. 203, 204, 211, and 219) have water with sulfate concentrations greater than 60 mg/L. Three of these are in, or very near, mines and the other is probably in contact with sulfide minerals. One of the wells (map no. 204), known to penetrate a mine, has water-quality characteristics similar to the mine water including a dissolved-solids concentration of 1,190 mg/L, a sulfate concentration of 560 mg/L, and a zinc concentration of 8,800 µg/L. Water from the other shallow wells is considerably less mineralized than the mine water.

Metals concentrations in water from the shallow wells are generally low, except for zinc. Zinc concentrations average 1,100 µg/L and are probably influenced by galvanized plumbing and (or) local sulfide mineral deposits as described by Feder and others, 1969, p. 34.

Results of the shallow well sampling indicate that there is not widespread movement of the highly mineralized mine water in the shallow aquifer.

Deep Wells

Water in the deep aquifer is a calcium magnesium bicarbonate type (fig. 3) and it can be distinguished from water in the shallow aquifer by its lower mineral content and lower calcium magnesium (Ca:Mg) ratio. The average Ca:Mg ratio (calcium and magnesium expressed in milliequivalents) is 2.3 for water in the mines, 2.3 for water in the shallow wells, and 1.7 for water in the deep wells. The lower ratio for water in the deep aquifer is indicative of the higher magnesium content of the dolomitic rocks.

The Ca:Mg ratios and concentrations of dissolved solids, sulfate, and zinc in water from Webb City Well No. 6 (map no. 305), Webb City Well No. 7 (map no. 308), and Carthage Well No. 1 (map no. 311) indicate mixing with water from the shallow aquifer. The water from the shallow aquifer may be leaking directly into these wells or may be entering the deep aquifer through faults, fracture openings, or wells that connect the aquifers.

The Oronogo-Duenweg mining belt extends along the east edge of Webb City. Water from deep wells on the east side of Webb City is more mineralized than water from deep wells on the west side.

In June 1972 the dissolved-solids concentration in water from Webb City Well No 10 was 840 mg/L This well is located near the mining belt and the high dissolved-solids content indicates the possibility of mine-water contamination of the deep aquifer on the east side of Webb City This well has been abandoned as a source of municipal water because of the high mineralization of the water (Raymond Lawrence, Supt Webb City Water Dept , oral commun , 1976)

SURFACE WATER

Center Creek, Turkey Creek, and Short Creek drain about 70, 18, and 5 percent of the mining area, respectively Some physical and hydrologic characteristics of these streams are given in table 6 All three streams flow westward and are characterized by alternating pools and riffles, and mixed sand, gravel and boulder bottoms

The lower part of Center Creek the largest of the three streams, flows through the northern part of the mining area and into the Spring River near the Missouri-Kansas state line Most of the baseflow originates in the headwater area, with little or no increase and some losses in the lower reach (Feder and others, 1969, p 54) About 1,970 acres of tailings piles having a total volume of approximately 38 million yd^3 (cubic yards), cover the lower part of the basin (Joseph R Miller, Ozark Gateway Council of Governments, written commun , 1977) Most of these tailings are in the Oronogo-Duenweg mining belt Discharges from at least three flowing mines enter Center Creek

Turkey Creek, south of and parallel to Center Creek, flows through the northern part of Joplin and into the Spring River in Kansas, just across the state line It is located in the center of the mining area Tailings piles are scattered throughout the basin and cover an area of about 600 acres, with a total volume of about 10 million yd^3. The flow and quality of water in Turkey Creek are greatly altered by sewage plant discharge at Joplin, industrial discharges, and mine-water discharge from at least one abandoned mine

Short Creek, south of and parallel to Turkey Creek is a small stream that originates just west of Joplin After crossing the state line it flows 4 3 mi (miles) in Kansas before entering the Spring River Although Short Creek has a total drainage area of 18 mi^2 (square miles) only about 7 6 mi^2 contribute to the flow at the state line Mining activities in the upper part of the basin have left about 185 acres (2 9 million yd^3) of tailings piles scattered on the surface

Tailings Areas

The distribution and size of tailings piles on the surface generally correspond to the distribution and size of mines beneath the surface However, some of the ore was removed from the area for processing and some of the tailings have been removed to be used for road surfacing and railroad ballast, or ground into sand for sand blasting The greatest concentration of tailings piles is in the Oronogo-Duenweg mining belt (fig 6), which is about 2 mi wide and 10 mi long, reaching from Oronogo to Duenweg This mining area is in the Center Creek basin, except for the southwestern edge which is in the Turkey Creek basin Outside the Oronogo-Duenweg belt the tailings piles are generally scattered and intermixed with woodlands and farmlands Regardless of the location, runoff and seepage from the tailings piles reach the main streams, either directly or through natural or man-made drainages

Surface drainage to Center Creek from the Oronogo-Duenweg mining belt is primarily by Mineral Branch, located in the center part of the belt (fig 1) It originates southwest of Prosperity and flows into Center Creek at Highway D about 1 5 mi upstream from Oronogo Another drainage, Stoutt Branch, originates in the mining belt southeast of Prosperity, but leaves the mining area and runs through farmlands and woodlands before entering Center Creek just downstream from Lakeside The Sunset mine (map no 109) and a nearby unnamed mine (map no 110) discharge about 1 ft^3/s of water to Mineral Branch at Carterville during periods of low flow Otherwise, Mineral Branch is dry upstream from Carterville and Stoutt Branch is dry throughout its length during periods of little or no rainfall but both carry large volumes of water during periods of heavy rainfall These two branches are important from the standpoint of the effects of the tailings areas on water quality in Center Creek

Reconnaissance --During the reconnaissance sampling in March 1976 water flowing at eight tailings sites was collected and analyzed to determine the variation in types and concentrations of major ions and minor elements as shown in table 7 in the back of the report The eight tailings sites are scattered throughout the area, but most are located in the Oronogo-Duenweg mining belt Sources of the water samples vary from seepage directly out of individual tailings piles to flow in ditches draining areas completely covered by tailings to flow in ditches draining areas that are only partly covered by tailings Water at two of the sites, Mineral Branch at Carterville and Leadville Hollow near Joplin, is derived in part from mines that discharge at the surface The samples were collected during a period of moderate rainfall while surface runoff was taking place

In table 8 characteristics and dissolved constituents of water from the tailings areas are compared with those for a March 1976 sample collected from Center Creek upstream from the mining area Water from the tailings areas is more mineralized than water from Center Creek near Fidelity and is a calcium sulfate type rather than calcium bicarbonate The higher sulfate concentrations reflect the oxidation and solution of sulfide minerals still present in the tailings

Chromium cobalt, mercury, nickel, and silver are present in tailings area water at about the same low concentrations as in water from Center Creek upstream from the mining area Aluminum, iron, and manganese concentrations are considerably higher in the tailings water, but these metals are generally nontoxic to aquatic animals Metals that are toxic to aquatic animals [illegible] --Characteristics and dissolved constituents of water flowing from eight tailings sites and Center Creek, March 1976

Character or constituent	Eight tailings sites			Center Creek near Fidelity, Mo
	Maximum	Minimum	Average	(one analysis)
Calcium (Ca) in mg/L---	230	15	95	45
Bicarbonate (HCO_3) in mg/L---------------	176	0	62	136
Sulfate (SO_4), in mg/L--	490	79	230	8 2
Dissolved solids in mg/L---------------	838	162	414	134
[illegible] conductance in [illegible] at 25°C	[illegible]	[illegible]	[illegible]	[illegible]
pH [illegible]	[illegible]	3 5	[illegible]	[illegible]
[illegible]	[illegible]	0	[illegible] 0	0
[illegible]	[illegible]	1	[illegible]	[illegible]
Chromium (Cr), [illegible]	[illegible]	0	[illegible]	0
Cobalt (Co), in µg/L	[illegible]	0	4	1
Copper (Cu), in µg/L	[illegible]	0	46	0
Iron (Fe) in µg/L------	[illegible]90	10	120	30
Lead (Pb), in µg/L------	1 300	0	380	4
Manganese(Mn) in µg/L--	360	40	200	0
[illegible] (Hg), in µg/L---	0 9	0 0	0 2	0 1
[illegible]) in µg/L----	30	7	[illegible]6	2
[illegible]g), in µg/L----	0	0	0	0
Zinc (Zn) in µg/L------	35,000	540	16 000	20

at low concentrations but occurred in the tailings water at moderate to high concentrations include zinc, lead, copper, and cadmium Of particular significance are the high concentrations of zinc Uniformly high zinc concentrations (11,000 to 35,000 μg/L) were in water at all six of the sites where 80 to 100 percent of the flow was considered to be derived from tailings seepage or runoff Water from the other two sites (map nos 14 and 28) was derived from predominantly nontailings areas and contained zinc concentrations of less than 2,000 μg/L The maximum concentration (35,000 μg/L) was in water with the lowest pH (3 5), but the pH of water from other sites with high zinc concentrations ranged from 4 9 to 7 2 Lead concentrations were generally less than 5 μg/L in water with pH values greater than 7 0, but were as high as 1,100 and 1,300 μg/L in the water with pH values of 4 9 and 3 5, respectively Copper concentrations were less than 16 μg/L except for the acid-water drainage sample (pH 3 5) which had the maximum concentration of 350 μg/L Cadmium concentrations ranged from 25 to 60 μg/L in water from the six sites where the flow was considered to be mostly tailings seepage and runoff, but were 1 and 3 μg/L at the two sites where only a small part of the flow was derived from tailings areas

In May 1976 specific conductance and pH were determined for 50 water samples collected from tailings seepage and drainage ditches located throughout the area Specific conductance ranged from 191 to 1,800 and averaged 588 μmhos/cm at 25°C and pH ranged from 3 5 to 7 9 and averaged 6 6 These values compare closely with those determined in the eight samples from which other characteristics and dissolved constituents were determined, table 8 The maximum specific conductance was for water in a drainage ditch receiving discharge from a mine and the minimum pH was for seepage directly out of a tailings pile

In samples from 24 open pits and lakes, specific conductance ranged from 177 to 1,800 and averaged 939 μmhos/cm at 25°C Some of this water is highly mineralized because of long exposure to sulfide minerals and calcium carbonate rocks However, pH values ranged from 3 2 to 8 2 and averaged 7 3, indicating that acid formed by the solution and hydrolosis of the soluble sulfates is neutralized by the calcium carbonate rocks Only three pH values were less than 7 0

Small area storm runoff --The area selected for storm runoff sampling (fig 7) is 7 0 acres in size The surface is 100 percent tailings, consisting mainly of a large tailings pile, but including parts of three smaller barren rock piles The proportion and types of material present appear to be representative of that found throughout the mining area Drainage from the 7-acre site is well defined and enters Stoutt Branch about 200 ft upstream from the reconnaissance site (map no 8)

A continuous-stage recorder and weir were installed at the sampling site (map no 7) so that runoff from the area could be computed On June 23, 1976, 5 14 in of rain fell on the area between 0430 and 1430 h (hours) Antecedent conditions consisted of several days dry weather with no flow at the site

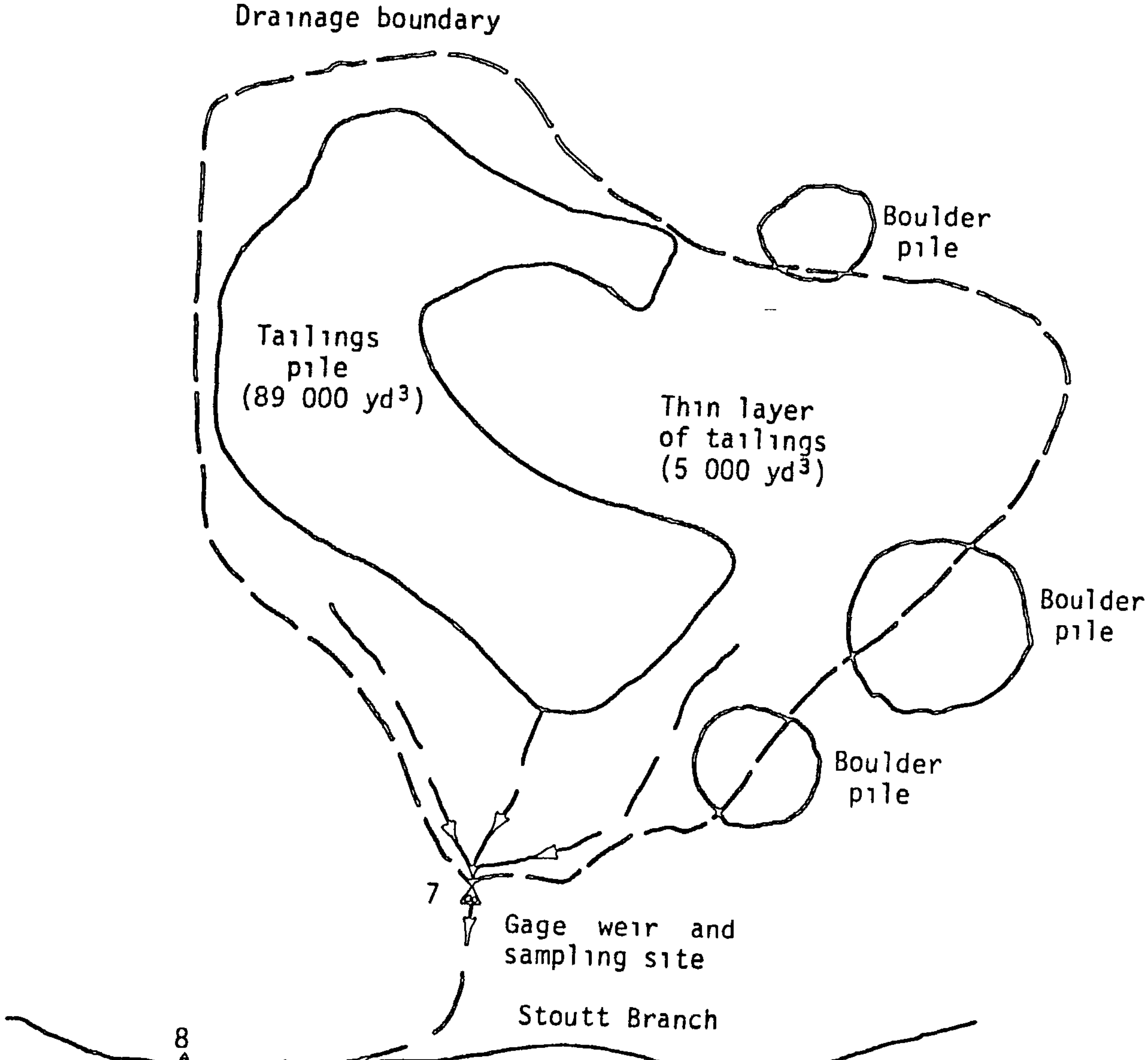


Figure 7 --Sketch of 7-acre tailings area storm runoff site (not to scale) Site numbers 7 and 8 refer to those on figure 1

Runoff at the gage increased from 0 ft^3/s (cubic feet per second) at 0430 h to a peak of about 10 ft^3/s at 0800 h, then gradually decreased to 0 6 ft^3/s at 1200 h Flow that occurred after 1200 h was mainly seepage out of the large tailings pile (fig 8) This seepage gradually decreased until it stopped on July 2, about 9 days after the runoff began Except for light rainfall that occurred on June 24 at 0300 h no additional rain fell between June 23 and July 2

Six samples were collected during the rise, one was collected near the peak and thirteen samples were collected during the recession, table 9 in the back of the report The first sample was collected on June 23 at 0540 h, about 30 min (minutes) after runoff started

The concentrations of dissolved inorganic constituents are inversely related to the amount of runoff as indicated by figure 9 The relation between dissolved solids and specific conductance for the storm runoff water is DS-(0 79XSC)-37, the standard error of estimate is 35 mg/L DS On June 23, dissolved-solids concentrations decreased from 348 mg/L at 0540 h to 38 mg/L at the peak (0755 h), then gradually increased to 392 mg/L at 2140 h Part of the increase to 664 mg/L on June 24 at 0840 h may be due to flushing caused by the shower that occurred at 0300 h Dissolved-solids concentrations decreased to 410 and 358 mg/L on June 25 and 28, respectively Changes in dissolved-solids concentrations reflect changes primarily in concentrations of calcium, zinc and sulfate

The range in concentrations of metals dissolved in the storm runoff water is given in table 10 Generally, the minimum concentrations occurred during peak runoff and maximum concentrations occurred near the beginning or near the end of runoff Zinc, cadmium, and lead are particularly significant because of their high concentrations (fig 10 and 11), and their high toxicity to aquatic animals The pH of the storm runoff water ranged from 4 2 near the beginning of runoff to 4 8 near the peak to 3 5 by June 28 when the last sample was collected

Concentrations of metals in the water-suspended sediment mixture (two of the samples) indicate that during storm runoff nearly all of the zinc is in solution, but large amounts of lead, aluminum, and iron are associated with the suspended sediment Small amounts of cadmium copper, and other metals are also sorbed to the sediment particles

On June 23 storm runoff samples were collected from Stoutt Branch near Prosperity (map no 8) at 1115 h, and Mineral Branch at Carterville (map no 12) at 1330 h (see table 7 in the back of the report) Although the flow had peaked, an estimated 120 ft^3/s was still flowing in Stoutt Branch The dissolved-solids concentration was 74 mg/L and pH of the water was 6 3 Concentrations of dissolved metals were low except zinc (5,000 µg/L) and cadmium (60 µg/L) The flow had also peaked in Mineral Branch but an estimated 400 ft^3/s of water was still flowing The dissolved-solids concentration was 236 mg/L and the pH of the water was 6 7 Concentrations of

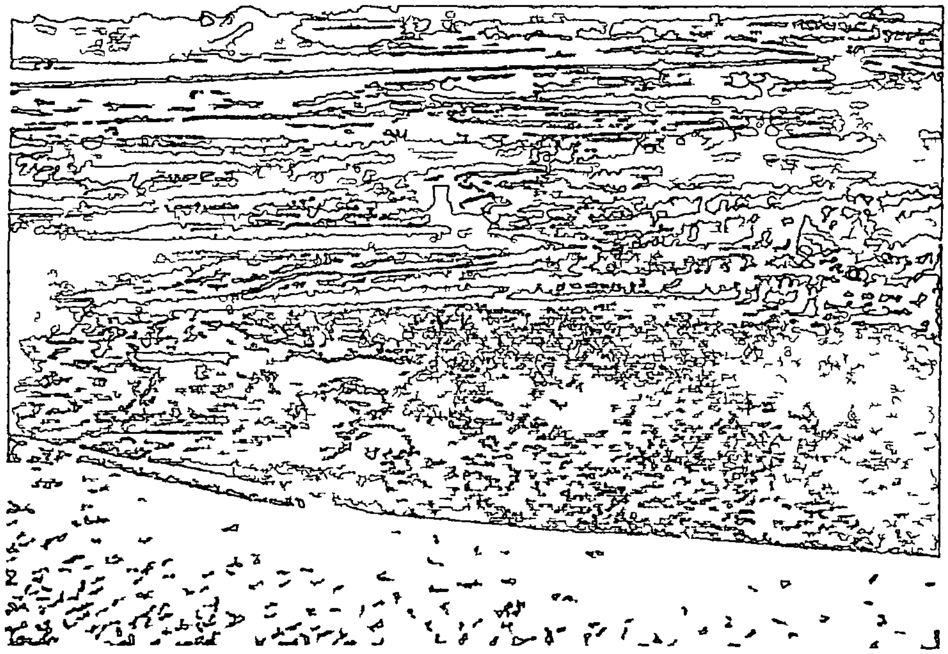


Figure 8 --Photograph of seepage from large tailings pile at 7-acre storm runoff site

Table 10.--Range in concentrations of dissolved metals in storm runoff from 7-acre tailings area, June 23-28, 1976

[Results in micrograms per liter]

Metal	Concentration	
	Minimum	Maximum
Aluminum (Al)	0	860
Cadmium (Cd)	46	1,400
Chromium (Cr)	0	0
Cobalt (Co)	0	20
Copper (Cu)	3	50
Iron (Fe)	30	340
Lead (Pb)	56	400
Manganese (Mn)	50	700
Mercury (Hg)	0.2	0.8
Nickel (Ni)	2	29
Silver (Ag)	0	0
Zinc (Zn)	3,800	200,000

water, there does not appear to be widespread dispersion of the highly mineralized mine water in the cherty limestones of the shallow aquifer The deep aquifer, composed of cherty dolomites and sandstone, is separated from the shallow aquifer by confining beds, but faults, fracture openings, or poorly constructed wells can connect the aquifers resulting in downward leakage The only places where there is evidence that this may be happening, however, is in the Webb City and Carthage areas In general, quality of water in the deep aquifer is excellent, but an insufficient number of deep wells are available to completely evaluate the quality of water beneath the mines

Runoff from tailings areas has high average concentrations of dissolved calcium (95 mg/L), sulfate 230 mg/L), and zinc (16,000 µg/L) Runoff from a few tailings piles has a low pH and, consequently, high concentrations of dissolved cadmium, copper, and lead However, these metals precipitate rapidly after mixing with high pH water, which ususally occurs very near the source

The significant effects of the abandoned mines and tailings areas on Center and Turkey Creeks appear to be about a 10-fold increase in dissolved zinc and a 25-fold increase in zinc and lead in the bottom material Based primarily upon analyses of samples collected from Center Creek upstream from the mining area, background concentrations appear to be about 40 µg/L dissolved zinc, 100 µg/g zinc in the bottom material, and 20 µg/g lead in the bottom material.

During low flow the increase in dissolved zinc concentrations in Center Creek are caused mainly by discharges from the Sunset and a nearby mine that enter Center Creek through Mineral Branch 1 5 mi upstream from Oronogo, subsurface seepage of mine water into Center Creek about one-fourth mile upstream from Oronogo, and discharge from the D C and E mine that enters Center Creek 0 4 mi downstream from Oronogo The high dissolved zinc concentrations are sustained during high flow by runoff from the tailings areas that is discharged mainly through Stoutt and Mineral Branches High zinc and lead concentrations in the bottom material are caused by deposition of tailings on the stream bottom, particularly downstream from Stoutt and Mineral Branches

The numerous alterations and contributions to the natural flow in Turkey Creek make it difficult and beyond the scope of this study to assess the specific sources of contributions from the mining area However, reconnaissance and seepage-run data show that all of Turkey Creek that has perennial flow (downstream from Duenweg) has high concentrations of dissolved zinc and zinc and lead in the bottom material As in Center Creek, the high dissolved zinc concentrations are caused by mine-water discharge and seepage during low flow and are sustained by tailings area runoff during high flow The Crackerjack mine discharges water to Turkey Creek through Leadville Hollow Tailings are mixed with the bottom material downstream from Duenweg where flow is perennial Some of the tailings are washed directly into the stream, but most are transported through Joplin Creek and the numerous small ditches that enter Turkey Creek

T bl 1 Gener l ed ecti o g l g r i s i th J pli n H ss i (fro F d nd t 1969)

(The st atig aphic nomenclat re ge ally follows th t of the U S Geological S ey and the M sou i Geol gi l Survey howe e there a e some lotions from th c rrent age of the U S Geol gi l Survey)

SYSTEM	SERIES	GROUP	S ig aphi Uni	Thi kne F	Phy ical Cha	Dep h t T p f F m io F	W be i g Cha
QUATERNARY	Hol o o		Alluvium	0-30	Un no lid od il nd nd grav l	Ou rop	Yi ld mall uppli f d m i nd k
PENNSYLVANIAN	D moinesian	Ch kee		0-100+	Sh l nd nd no wi h bed f coal	Ou rop	Yi ld li l wa hallow d g well
MISSISSIPPIAN	Ch t r		Ca rvill F rma fon	0 100	Lim on h l nd il no g nerally found filling d p i i nd lying ks	Ou op 50	Doe no yi ld wa well
	M e m		W aw F rma ion	80 150	Do lim ne i h ome h	Ou p 150	Yi ld li l p i l d l h l
	O a		Bu ling nd Keokuk Lime ne	50 150	Dens h y lim ne ome im ine li d wi h in nd load	Out p 300	Yi ld li l wh ma i b ca yi ld 100 gp in b i d S l i he l may yi ld l ge ppli
			El y F rma io	30±	Fine gr i d very h y lim ome im ll ch t nd minor li ed wi h i nd l d	Ou rop 450	Ge lly yi ld d qua pply f dome i and k ly ove 50 gp S ppli m y p ing
			R d Sp ing F rm i	5 100	Da k ry h y rgill ous lime ome ime ine li d wi h in nd l d	Ou rop 500	Ge lly yi ld d qua d m i k upply S ppli many p i g
			Pi F rma ion	10 30	Ch y doloni i lime ne i pp po i il y d lomi i lowe p i	100 600	i ld ry mall q f
	Kinderh ok		No h iew F rm i	0-15	Sh l haly lim b in f h	125 625	C fi g bed
			Comp on F m i	0 20	Sh ly lim on	125 625	Ge lly d no yi ld
			Ba h lo F rma ion	0 0 5	Sand ne	125 625	Do no yi ld well
DEVONIAN			Cha noog Sh l	0 10	Fi il bl k bo hal b hrough mo f	150 500	C fini g b d
ORDOVICIAN	L		Co Dolomi	200±	Ch y d l i i m nd ne bed	150 650	Yi ld mall q i f
			J ff City Dolomi	200±	Ch y d lomi	350 850	Yi ld mall q i i f
			ld ux F rm i	175+	Ch y d lomi d ev l nd b d	550 1 000	Ge lly y l good pply f m p li b 50 150 gp
			Ga onad Dol i	300±	Ch y lim ne nd d lomi d ne b d b f f rma io	700 1 150	Yi ld mall uppli f
CAMBRIAN	Upp		E nd P i Dolomi	200+	Dolomi i h dru y h i lowe 50 f	1 000 1 450	Ge lly yi ld good pply f p i lly f lowe p i b we 50 00 gp
			De by Do run Do i nd Do ne ro F rma ions ndiff i d	150±	Silty d l om il nd h l	1 200 1 650	i ld mall q i i f
			Lamo S nd ne	0 150	Qua so nd ne	1 350 1 750	Yi ld ry ld bly F rma ion may b b P carb i high
PRECAMBRIAN					G i nd rhyoli	1 350 1 850	Ge lly doe no yi ld

Aquifer labels spanning rows in the water-bearing column: "Sh ll Aq if" (Burlington and Keokuk to Reeds Spring) and "D p Aq if" (Cotter Dolomite to Lamotte Sandstone).

Table 2 Wate q lity data for ol s

STATION NUMBER	MAP NUMBER	MINE NAME	DATE OF SAMPLE	TOTAL DEPTH OF HOLE (FT BELOW LSD)	DEPTH TO WATER SURFACE (FT BELOW LSD)	DEPTH TO SAMPLE COLLECTION (FT BELOW LSD)	DIS SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL CIUM (CA) (MG/L)	DIS SOLVED MAG NE SIUM (MG) (MG/L)	DIS SOLVED SODIUM (NA) (M /L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	BICAR BONATE (HCO3) (MG/L)
370516094265501	101	ST REGIS	76 05 25	208	28 00	38	8 6	120	9 7	2 9	1 2	180
			76 05 25	208	28 00	198	23	290	19	6 5	3 5	64
370519094251601	102	KING WILLIAM	76 05 25	206	44 00	54	8 0	87	4 0	2 7	4	116
370527094360901	103	GIBSON	76 05 27	179	10 00	20	12	160	6 5	8 2	6	216
370613094323801	104	CRACKERJACK	76 05 28	106	0 00	10	9 7	250	13	11	2 0	260
[illegible]	105	VOGEY	76 05 25	170	21 00	31	13	360	6 9	6 8	1 6	98
[illegible]	106	NOWATA	76 05 25	188	52 00	62	9 1	69	2 9	2 5	9	30
37071609 255801	107	FLORINE	76 05 26	197	52 00	62	11	130	5 3	5 0	6	158
[illegible]	108	MCGREGOR	76 05 26	172	45 00	55	17	97	3 0	2 5	1 6	52
			76 05 26	172	45 00	162	18	240	4 9	4 2	1 6	148
[illegible]	109	SUNSET	76 10 21		0 00			530	8 0		—	154
[illegible]	110	UNNAMED	76 10 21		0 00		-	480	7 3	-		116
[illegible]	111	ICE PLANT	76 05 26	185		90	12	480	8 8	7 3	1 7	182
[illegible]	112	RHEA	76 05 26	116	3 00	13	12	450	8 6	8 0	1 9	184
[illegible]	113	STAR 43	76 05 27	163	13 00	23	11	100	5 7	2 9	8	78
			76 05 27	163	13 00	153	9 6	350	7 7	7 0	1 4	172
[illegible]	114	UNITY	76 05-27	155	0 00	10	10	320	8 0	7 5	1 6	180

DATE OF SA PLE	DIS SOLVED SULFATE (SO4) (MG/L)	DIS SOLVED CHLO RIDE (CL) (MG/L)	DIS SOLVED FLUO RIDE (F) (MG/L)	DIS SOLVED SOLIDS (RESI DUE AT 180 C) (MG/L)	DIS SOLVED SOLIDS (SUM OF CONSTI TUENTS) (MG/L)	HA D NESS (CA MG) (MG/L)	NON CAR BONATE HARD NESS (MG/L)	ALKA LINITY AS CACO3 (MG/L)	SPE-CIFIC CON DUCT ANCE (MICRO MHOS)	PH (UNITS)	TEMPER ATURE (DEG C)	DIS SOLVED OXYGEN (MG/L)	PER CENT SATUR ATION
76 05 25	190	1 5	1	440	426	340	190	148	610	7 2	15 5	4 3	43
76 05 25	960	4 9	5	1570	1390	800	750	53	1730	5 7	16 0	5	5
76 05 25	140	6	2	327	307	230	140	95	460	7 3	15 0	5 4	53
76 05 27	220	1 8	2	495	497	380	200	177	670	6 9	15 0	5	5
76 05 28	480	7 2	4	961	904	680	460	213	1120	7 0	14 5	2 4	23
76 05 25	830	3 1	6	1390	1290	930	850	80	1530	7 1	16 5	9 0	92
76 05 25	170	1 1	1	324	285	180	160	25	430	7 3	14 5	8 0	78
76 05 26	210	1 1	4	476	442	350	220	130	600	7 6	15 0	9 0	89
76 05 26	200	9	3	427	362	250	210	43	535	6 9	16 0	9 0	91
76 05 26	530	1 5	7	945	889	620	500	121	1100	6 5	16 0	3	3
76 10 21	1100		-	1900		1400	1200	126	2100	6 4		-	
76 10 21	1100		-	1750		1200	1100	95	1970	7 1			
76 05 26	1100	4 9	1 2	1740	1720	1200	1100	149	1810	6 8	14 5	3 5	34
76 05 26	1000	5 6	1 2	1760	1590	1200	1000	151	1850	6 8	15 0	8	8
76 05 27	240	1 1	7	447	414	270	210	64	585	6 6	15 5	8	8
76 05 27	710	4 2	9	1280	1190	910	760	141	1300	6 8	15 0	6	6
76 05 27	700	4 6	9	1210	1150	830	680	148	1280	6 6	14 5	1 4	14

DATE OF SA PLE	CARBON DIOXIDE (CO2) (MG/L)	DIS SOLVED ALUM INU (AL) (UG/L)	DIS SOLVED CAD MIUM (CD) (UG/L)	DIS SOLVED CHRO MIUM (CR) (UG/L)	DIS SOLVED COBALT (CO) (UG/L)	DIS SOLVED COPPER (CU) (UG/L)	DIS SOLVED IRON (FE) (UG/L)	DIS SOLVED LEAD (PB) (UG/L)	DIS SOLVED MAN GANESE (N) (JG/L)	DIS SOLVED MERCURY (HG) (UG/L)	DIS SOLVED NICKEL (NI) (UG/L)	DIS SOLVED SILVER (AG) (UG/L)	DIS SOLVED ZINC (ZN) (UG/L)
76 05 25	18	10	13	0	0	3	40	6	0	6	14	0	3000
76 05 25	204	0	30	0	37	2	67000	28	800	6	98	0	6300
76 05 25	9 3	10	29	0	0	3	30	6	10	7	18	0	6400
76 05 27	44	10	4	0	5	0	60	24	60	6	20	0	540
76 05 28	42	10	4	0	0	0	20	8	0	6	47	0	2500
76 05 25	12	0	31	0	0	7	170	6	100	5	52	0	17000
76 05 25	2 4	10	41	0	4	4	50	8	330	7	19	0	14000
76 05 26	6 4	10	8	0	0	3	30	9	0	6	12	0	630
76 05 26	10	0	31	0	0	1	30	10	20	6	43	0	14000
76 05 26	75	20	41	0	6	3	2500	10	150	4	50	0	12000
76 10 21	90	--	2	- -			17000	11	550			-	12000
76 10 21	15	-	4				20	7	340			--	12000
76 05 26	46	10	27	0	7	3	40	15	110	3	74	0	12000
76-05 26	47	10	26	0	7	1	200	9	110	4	86	0	12000
76 05 27	31	10	54	0	3	1	30	7	400	4	40	0	13000
76-05 27	44	0	49	0	4	1	30	7	70	5	62	0	13000
76 05 27	72	10	31	0	3	0	50	8	10	4	60	0	10000

Table 3 --Water-quality data f wells i the h llow aq ife

STATION NUMBER	MAP NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL CIUM (CA) (MG/L)	DIS SOLVED MG-NE SIUM (MG) (MG L)	DIS SOLVED SODI (NA (MG/L)	DIS SOLVED PO-TAS SIUM ( ) (MG/L)	BICAR BO ATE (HCO3 (G/L)	DIS SOL ED SULFATE (SO4 G L)	DIS SOL ED CHLO RIDE CL (MG L)	DIS-SOL ED FLUO-RIDE (F) (MG L)	DIS-SOLVED SOLIDS (RESI DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI TUENTS (G/L)
370316004275301	201	76-00 11	200	0 6	69	0 0	11	7	160	15	15	3	214	100
370630004365201	202	76-00 11	106	0 6	69	2	0	5	17	45	3	2	230	220
370500004256001	203	76-00 09	170	0 0	110	4 2	5 2	0	160	110	3 9	1	364	322
[illegible]	[illegible]	76-00 09	300	10	320	0	19	7	300	380	38	[illegible]	1900	[illegible]
370620004393301	205	76-00 11	210	12	26	2 0	10	2 4	52	40	17		17	152
370620094300501	206	76-00 10	247	9 2	100	11	16	2 0	290	59	2A	1	600	369
370645094230001	207	76-00 12	--	0 1	80	0 5	5 5	0	27	9 6	5 2	1	270	256
370659009632 901	208	76 00 10	205	0 3	70	6 1	0	0	276	9 3	1 7	1	232	2 5
370735094252001	209	76-00 10	200	0 4	62	4 7	9 6	1 9	44	54	8 1	1	232	172
370029004230701	210	76 00 12	362	0 1	46	17	13	1 2	244	11	3 6	0	208	221
370034094330601	211	76-00 10	101	11	100	5 0	20	8 5	216	120	12	2	424	304
370041094291601	212	76-00 10	250	0 6	05	3 0	6 2	9	260	60	3 6	1	310	310
370041094355001	213	76-00 11	--	0 2	74	7 0	3 6	7	252	8	2 1	3	232	223
370053094251501	214	76 00 10	255	0 5	83	2 5	3 6	6	212	0	1 0	1	258	254
37005300 303501	215	76-00 12	230	0 1	05	15	6 6	1 2	344	11	2 0	1	294	299
370950004261101	216	76-00 12	--	0 5	09	4 2	2 6	5	252	2	1 7	1	284	27
371006094203401	217	76-00 12	100	0 4	70	6 2	4 2	7	22	23	2 5	1	240	234
371016094273601	218	76 00 10	206	0 3	03	1 1	1 7	3	218	35	2 1	1	236	2 1
371033094305201	219	76 00 12	205	0 1	99	36	14	2 0	288	180	2 6	5	516	485
371100094234401	220	76-00 11	205	0 4	65	5 6	3 3	1 2	208	16	1 0	1	222	205
37111 09 290601	221	76-00 10	300	9 6	02	0 1	7 7	3 4	236	54	7 2	2	300	291

DATE OF SA PLE	HARD-NESS (CA MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	ALKA LINITY AS CACO3 (MG/L)	SPE CIFIC CON-DUCT ANCE (ICRO-MHOS)	PH (UNITS)	TEMPER ATURE (DEG C)	DIS SOLVED ALUM INUM L) (UG/L)	DIS-SOLVED CAD MIU (CD) (UG/L)	DIS SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS SOLVED LEAD (B) (UG/L)	DIS SOLVED MAN-GANESE (MN) (UG/L)	DIS SOLVED NICKEL (I) (UG/L)	DIS SOLVED ZI C (ZN) (UG/L)
76 00 11	150	13	130	376	7 6	16 5	20	4	4	0	9	0	1	60
76 00-11	100	39	143	480	7 0	17 5	20	4	2	20	6	10		360
76 08 09	290	100	131	620	6 1	22 0	20	16	5	0	2	30	10	360
76 00 09	000	900	00	1400	6 7	23 0	50	0	0	930	[illegible]	000	04	0000
76 00 11	76	36	43	265	6 4	20 0	20	2	0	2600	9	100	44	5000
76 00 10	300	57	230	608	7 0	16 0	20	0	0	20	15	10	0	250
76 00 12	240	14	225	540	7 3	16 0	20	1	7	20	0	10	2	1300
76 08 10	220	0	226	450	7 2	19 0	20	0	0	250	16	10	0	680
76-08 10	170	160	36	415	5 3	16 0	20		2	0	3	0	3	430
76 00 12	100	0	200	420	7 6	17 0	40	3	0	10	13	10	0	120
76 00-10	270	97	177	690	7 0	18 0	20	1	2	40	8	0	3	30
76 00 10	250	40	213	545	7 1	16 5	20	1	0	2500	8	50		20
76 00 11	210	7	207	420	7 4	17 0	20	0	0	050		50	2	20
76 00 10	220	44	174	445	6	16 0	20	1	2	0	3	10	5	1000
76 00 12	270	0	282	530	7 1	16 5	20	1	6	100	3	10	0	250
76 08 12	240	33	207	320	7 4	16 5	20	7	4	30	38	10	2	1 00
76 00 12	220	37	104	320	7 4	15 5	20	1	0	40	5	60	2	560
76 00 10	210	33	170	625	7 2	16 5	20	6	2	20	13	10	2	900
76 00 12	00	100	236	735	7 3	16 5	20	2	0	0	10	10	0	920
76 00 11	100	15	171	376	7 2	16 5	0	3	4	0	22	0	0	250
76 08 10	240	40	104	520	7 1	17 5	40	30	3	20	15	10	7	1200

T bl 4 —U t quality data Po wall 1 the deep quif r

STATION NUMBER	MAP NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DIS SOLVED SILICA (SIO2) (MG/L)	DIS SOLVED CAL CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE SIUM (MG) (MG/L)	DIS SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS SIUM (K) (MG/L)	BICAR BONATE (HCO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS SOLVED SOLIDS (RESI DUE AT 180 C) (MG L)	DIS-SOLVED SOLIDS (SUM OF CONSTI TUENTS) (MG/L)
370416006305201	301	76-09 08	990	9 2	33	15	3 2	1 9	160	15	3 1	2	145	160
370 33094265501	302	76-09-08	1228	9 2	65	10	3 0	2 1	202	14	1 9	0	227	193
370532094230901	303	76-09-08	1482	9 5	46	10	6 0	2 1	170	40	3 3	1	224	220
370810094204501	304	76-09-09	1475	0 3	32	16	3 3	1 0	152	14	2 0	2	142	152
370027006273001	305	76-09 07	1015	9 7	69	22	6 3	2 3	190	110	2 5	2	321	318
3700 2094283301	306	76-09-09	930	9 3	32	14	3 6	2 0	160	17	2 6	3	128	160
370050094221101	307	76 09 08	1473	9 6	34	15	0 5	1 0	166	15	5 9	1	166	172
37005200 273601	308	76 09 07	1415	18	48	10	4 3	1 0	226	25	2 1	2	22	220
370911094202901	309	76-09 09	1500	9 4	36	15	5 6	2 0	180	15	2 9	2	159	179
370956094322001	310	76 09 08	1400	9 2	29	13	40	3 1	170	15	66	5	230	2 2
371030096175001	311	76 09 08	1250	10	90	11	8 0	2 0	250	39	10	1	325	298
371040094335601	312	76-09 08	900	8 0	40	19	7 2	3 1	210	18	9	5	206	205
371120096283101	313	76 09 07	1335	9 6	40	19	9 3	2 5	230	20	6 1	3	184	220
371120096283201	314	76 09 07	925	9 1	46	20	5 8	2 9	224	2	3 9	3	215	221

DATE OF S MPLE	H RD-NESS CA G) (MG/L)	NON-CA BON TE H RD NESS (MG/L)	ALKA LINITY AS C CO3 (MG/L)	SPE CIFIC CON-DUCT NCE (ICRO-MHOS)	PH (UNITS)	TE E ATURE (DEG C)	DIS SOLVED ALUM INUM (L) (UG/L)	DIS SOLVED CAD MIU (CD) (UG L)	DIS SOLVED COPPER (CU) (UG/L)	DIS-OLVED IRON (FE) (UG/L)	DIS SOLVED LEAD (PB) (UG/L)	DIS-SOL ED AN-GANESE (MN (UG/L)	DIS OLVED NIC EL (NI) (UG/L)	DIS SOLVED ZINC (ZN (UG/L)
76-09-08	140	13	131	282	7 7	19 8	10	0	0	0	3	0	0	20
76 09 08	190	21	166	338	7 5	10 0	0	0	2	0	6	20	0	60
76 09 08	180	40	146	381	7 7	19 0	0	2	3	0	11	10	0	60
76 09 09	1 0	13	125	270	7 7	19 0	10	0	0	10	2	10	0	20
76 09-07	260	108	162	515	7 6	10 5	10	0	0	170	1	20	0	160
76 09 09	140	6	131	285	7 7	18 5	10	0	2	10	2	20	0	40
76 09 08	150	11	136	328	7 0	19 5	0	2	0	40	11	10	0	20
76 09-07	190	10	18	392	7 6	19 6	10	0	0	110	2	10	2	80
76 09-09	150	0	15	312	7 6	18 5	0	0	0	20	3	20	0	20
76 09 08	130	0	1 6	635	7 5	19 0	10	0	0	78	5	10	0	0
76 09 08	270	58	212	515	6 8	17 0	10	2	5	10	31	20	2	350
76 09-08	180	6	172	368	7 6	18 0	10	0	16	70	3	10	0	20
76 09 07	100	0	189	386	6 9	19 5	10	0	0	18	5	10	0	60
76 09 07	190	0	184	415	7 0	17 5	20	0	0	170	3	20	0	80

Reference # 2

A mining research contract report
APRIL 1983

STUDY OF STABILITY PROBLEMS AND HAZARD EVALUATION IN THE MISSOURI PORTION OF THE TRI-STATE MINING AREA

Contract J0100132
Missouri Department of Natural Resources
Division of Geology and Land Survey

U S DEPARTMENT OF THE INTERIOR
MINERAL INDUSTRIES
BUREAU OF MINES

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

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16. Abstract (Limit 200 words)

A two year investigation has disclosed 469 hazardous sites resulting from past zinc lead mining in the vicinity of Joplin Missouri Aerial photo analysis fieldwork library research and personal interviews were conducted to locate and describe the abandoned mining areas and their associated hazards Open shafts subsidence pits and other mine related dangers exist in areas easily accessible to the public Accidents involving humans and livestock have been reported Some recent damage to buildings and roads can be attributed to the collapse of underground mine workings A few landowners have employed successful methods of safeguarding dangerous sites In addition some surface reclamation has been effected by gradual removal and use of mine and mill waste rock with subsequent leveling and reuse of the land Other than backfilling shafts nothing has been done to stabilize undermined areas A continuing problem is indicated Under present laws most government reclamation funds are designated for coal mined lands A comprehensive program of hazard control and monitoring for the entire study area is warranted

17 Document Analysis a. Descriptors

Mines Shafts Open Pits Subsidence Hazards Tailings Ponds Waste Piles

b. Identifiers/Open-Ended Terms

Tri State District Hazard Assessment Stability Problems

c. COSATI Field/Group

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15 Trimm, W L Waste Products in Missouri With Potential Highway Application Missouri Highway and Transportation Department, Study 81-2, 1982, 65 pp

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tailing sludges and mill ponds, but most are now breached The small size and shapes of the individual ponds were difficult, sometimes impossible, to detail at the required scale The majority of the ponds in the district were of this type Elaborate revetments were constructed in the mining areas to control surface drainage, they were not included in the interpretation Some Kansas piles and ponds shown on the Joplin West and Carl Junction map plates are numbered and correspond to descriptive information recorded in table A-3 (appendix A)

Tabulations

Three tables (appendix A) were prepared to present specific information pertaining to the various numbered sites appearing on the map plates All tabular data pertaining to sites in the Kansas portions of the Joplin West and Carl Junction quadrangles were provided by James R McCauley, principal investigator for the Kansas study area

Tables A-1 and A-2 list descriptive site information for the hazards shown on plates 2A-D Four-part site numbers are used to key tabular data to particular hazards From left to right, each site number gives the following locational information 1) township, 2) range, 3) section, and 4) hazard number within that section, as shown on the map plates Thus, the site number 28-32-16-10 refers to the following location township 28, range 32, section 16, hazard 10 within that section Data pertaining to open shafts are contained in table A-1 Information on subsidences and open pits is recorded in table A-2 Both tables list hazardous sites by quadrangle, beginning with Joplin East and proceeding clockwise through the study area Data for hazards lying in the Kansas portions of the Joplin West and Carl Junction quadrangles are listed at the end of each table

Table A-3 contains descriptive site information for numbered chat piles and tailings ponds on the Kansas portions of plates 3-B and 3-C

LOCATION, TOPOGRAPHY, AND HYDROLOGY

The Missouri study area (fig 1), measuring approximately 625 km^2 (240 mi^2), is included within the following USGS 7½-minute quadrangles Joplin East, Joplin West, Carl Junction, and Webb City, an area comprising a large portion of southwestern Jasper County and a small part of northwestern Newton County In the project area, Interstate 44 is the major highway and Joplin is the largest city

The Missouri portion of the Tri-State Mining District lies on the northwest flank of the Ozark uplift The land surface slopes westward toward Kansas and Oklahoma Elevations vary from 360 m (1200 ft) on the east to 240 m (800 ft) on the west Relief in the area ranges from 24 m (80 ft) on the north to 75 m (250 ft) on the south

The study area lies entirely within the Arkansas River drainage basin (U S G S Hydrologic Unit #11070207) Spring River, which flows generally westward, is the main drainage channel in the area Major tributaries, also flowing west, include Center Creek, Turkey Creek, Short Creek, and Shoal Creek. At the height of active mining, circa 1910, in the Duenweg-Webb City-Oronogo field (east half of study area), numerous drainage canals were constructed to divert rain and mine waters away from important production-shaft areas These canals remain intact as wet-weather tributaries of Center Creek

Springs in the project area have been measured to flow as much as 0 6 m^3/sec (20 ft^3/sec), or 9000 gal/min during wet weather (6, p 26) Several open shafts were found to have artesian flows averaging about 0 06 m^3/sec (2 ft^3/sec), or 900 gal/min

Two aquifers exist in the area, a shallow one, in Mississippian limestone, is in the mineralized rock zones, a deep one, in Cambro-Ordovician sandstone and dolomite, is well below the ore-bearing strata (6, p 1)

GEOLOGY, STRATIGRAPHY, AND STRUCTURE

The zinc-lead ore deposits of the Tri-State region are in cherty Mississippian limestones The chert occurs as nodules in limestone, and as interbedded layers From oldest to youngest, the Pierson (Fern Glen), Reeds Spring, Elsey (Grand Falls), Burlington, Keokuk, Warsaw, and Carterville Formations were the host rocks for most of the zinc-lead mineralization Their total thickness in the area exceeds 120 m (400 ft) (9, p 59) Figure 2 is a generalized stratigraphic section for the Joplin District

Small outliers of the Pennsylvanian Cherokee Formation (shales and sandstones) unconformably overlie the Mississippian rocks in some localities Rich ore bodies are associated with these Pennsylvanian sediments where they have filled dissolution structures (sinkholes and collapses) in the Mississippian strata

Throughout the Tri-State District, extensive chemical dissolution of carbonate rock produced horizontal and vertical channels, porous breccia zones of insoluble cherts, and other subsurface cavities (14, p 7) These voids proved excellent repositories for ore precipitation and concentration from mineralized fluids

Structure in the area is limited to gentle folding, the axes generally plunging northwest The regional one-degree dip of the sedimentary formations is also northwestward, away from the Ozark uplift (4, p 411) The Joplin anticline and adjacent Webb City syncline are believed to have influenced the localization of rich trends of mineralization around Joplin and Webb City (11, p 38) Minor faulting and fracturing provided increased zones of rock dissolution and, eventually, channels for ore-bearing fluids

ORE DEPOSITS

The major ore minerals of the Tri-State District are sphalerite (zinc sulfide) and galena (lead sulfide) Marcasite, pyrite (iron sulfide), and chalcopyrite (copper-iron sulfide) are of minor importance Small amounts of greenockite (cadmium sulfide) are also present (14, p 8)

Near-surface oxidation of these sulfides has produced commercially important amounts of smithsonite (zinc carbonate), cerussite (lead carbonate), and hemimorphite (zinc silicate) Gangue minerals include quartz, calcite, and dolomite, the quartz occurring as chert and secondary jasperoid A coloring agent in the jasperoid is a dark, opaque material, bitumen, residual organic matter that appears throughout the mining district, usually in tar-like or hardened masses coating rock surfaces (14, p 8), it is believed to have been instrumental in the chemical reduction of some of the sulfide ores (7, p 3)

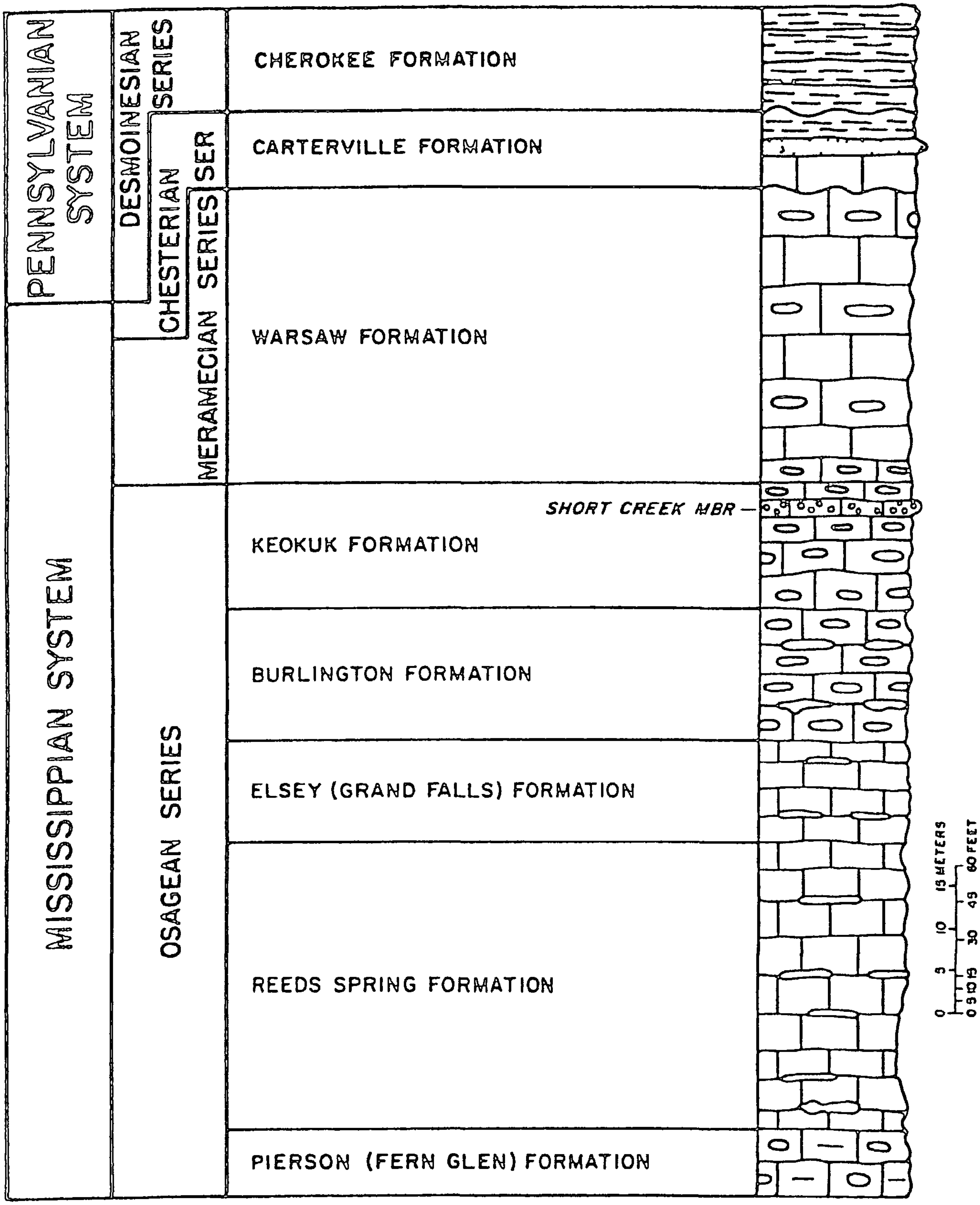


FIGURE 2 – General stratigraphic section Joplin District (modified from 9 pp 59-81)

In Missouri the ore deposits of the Tri-State District have been classified into two main divisions 1) upper-ground, or "broken-ground," deposits and 2) lower-ground, or "sheet-ground," deposits The upper-ground ore zones are associated with incompetent layers of porous chert breccias and loose, unconsolidated masses of clay-like materials, both being remnants of intensive underground solution processes The lower-ground ores are present in more competent beds Mineralization has filled flat, sheet-like voids dissolved out between insoluble chert layers

The ore bodies have several basic shapes, their irregular boundaries determined by the variable host chambers and channels within the dissolved carbonate rock strata (16, pp 59-60) "Runs," long, relatively narrow bodies, tend to occupy the chert breccias and enlarged solution joints of the upper-ground "Circles," arcuate, oval, or circular bodies, develop about shale-filled sink and collapse structures "Sheets," flat, tabular bodies of considerable areal extent, occur in the lower-ground and are intercalated with thin chert beds

The genesis of the Tri-State ore deposits has been studied and debated for over a century Several processes have been proposed to explain the manner in which the ore-bearing solutions were introduced into Mississippian strata in this region (19, p 469) Two theories have been generally accepted as the most satisfactory in explaining these deposits One states that downward-percolating groundwaters, rich in metals, entered all available subsurface dissolution structures and precipitated the ores (5, p 14), the other, that artesian-circulating groundwaters transported the metals through favorable structural weaknesses, ascended into the solution cavities, and precipitated the ores (4, pp 428-429) Further studies will undoubtedly lead to additional theories in attempting to prepare a precise reconstruction of the events responsible for one of the most productive zinc-mining districts in the world

MINING HISTORY, PRODUCTION, AND RESERVES

The discovery of lead ores in the Joplin, Missouri, area during 1848 marked the beginning of mining in the Tri-State District (16, pp 56-57) The associated zinc ores were originally discarded for lack of an efficient, economical technology for recovery of the zinc About 1870, however, the extension of railway lines into southwestern Missouri and the development of new milling and smelting techniques led to the first production of zinc in the area (18, p 127) By 1875, Missouri had become the leading zinc producer in the nation Early mining tracts were small, some leases measuring as little as 60 x 60 m (200 x 200 ft), or about 1 ac (12, pp 19-20) Mining was confined to the upper-ground ore zone, within the first 30 m (100 ft) or so of the surface Due to the "broken" nature of this ore zone, drifting operations were limited, therefore, many shafts were sunk at close intervals In fact, Missouri laws required two shafts for each property, usually within 90 m (300 ft) of one another (8, p 150) As a result, thousands of production and prospect shafts were sunk in the district Table 2 shows the numerical distribution of these shafts, as determined for each quadrangle in the study area

As easily accessible mineralized areas were exhausted, shafts were sunk deeper, eventually encountering the lower-ground ore zone, below 30 m (100 ft) 'Sheet-ground" ore bodies, ranging in thickness from 2-4 m (7-14 ft), were mined by the room-and-pillar method (3, p 9) From 1902-1907, Harry Kimball of the American Zinc, Lead, and Smelting Company developed mechanized volume-mining methods that allowed these low-grade, but very extensive, "sheet-ground" areas to become profitable before World War I

(12, pp 21-27) High prices for zinc and lead concentrates during the war led to a mining boom, lasting until 1917, in the Joplin and Webb City fields of Missouri A severe collapse of metal prices followed the conclusion of World War I and caused a rapid decline in mining from which the Missouri Tri-State has never recovered Operations were shifted to Oklahoma and Kansas, where extensive deposits had been discovered and large-scale projects were already underway

By 1920, most major mines in Missouri had closed, and the Picher Field of Oklahoma had become the leading producer of zinc in the United States, continuing that prominence through 1946 Several districts in Kansas had also attained high production totals During World War II, increased metal prices and government subsidies permitted operators of some Missouri 'sheet-ground" mines to rework low-grade ore deposits at a small profit (4, p 403) The last significant production in Missouri was in 1957, but intermittent output continued into the late 1960's (16, p 58) A summary of Missouri's production is given in table 4

As indicated by table 5, considerable ore reserves remain within the Missouri portion of the Tri-State District Approximately 87 percent of the Missouri ore reserves were under water at the end of 1947 (13, pp 17-18) Most of these flooded deposits are in the Duenweg-Webb City-Oronogo "sheet-ground' field, the largest single area of remaining ore reserves in the Tri-State District

MINE AND MILL WASTE UTILIZATION

Before 1900, in the Missouri portion of the Tri-State District, state laws and local mining methods dictated that existing small tracts and leases be used by the mining companies (8, pp 148-150), who could, in turn, sublease them or portions of them to individual miners Many concentrating mills and plants were necessary for individual mining companies to calculate their royalties The size of each mill varied with the size of the mine or mines being served, and their associated wastes and disposal areas varied accordingly

Waste products (tailings) consist of varying sizes of angular chert fragments chats (1 cm, or 3/8 in, to 35 mesh), sands (35 mesh to 65 mesh), and slimes (65 mesh to 200 mesh) (14, p 13) A large accumulation of graded tailings is shown in figure 3 Boulders (20 cm, or 8 in, and larger) consist of chert and limestone with associated minerals and gangue Figure 4 illustrates a large boulder pile Usually the boulders and chats are mixed and stacked near the mill In many cases, these piles are directly over underground workings, increasing the roof load and the chances of subsidence In figure 5, the tops of "sunken" waste piles are visible in the central portion of the subsidence pit The slimes are concentrated in settling ponds controlled by earthen dikes

Remilling of tailings resulted in the relocation of many chat piles Chats have been processed for use as railroad ballast, road metal, and aggregates in asphalt paving and portland cement concrete Sands and smaller sizes have been used for abrasives, roofing granules, pipe coatings, and filter sands (16, p 168) Boulders have been used for fill material and rip-rap, with some crushing to smaller sizes for use as ballast It has been estimated that 80 percent of the mine wastes have been removed and recycled (14, p 13) The Independent Gravel Company operates two recycling plants in the area, reporting approximately 230 m^3 (300 yd^3), or 400 short tons, per day to produce sand blasting

TABLE 4 — Mine production statistics for Missouri portion of Tri State District 1907 1945[1]

Unit	Material treated		Metal recovered	
	Crude ore	Old tailings	Zinc	Lead
Metric tons	108 026 062	4 016 877	3 157 656	780 215
Short tons	120 028 958	4 463 197	3 508 507	866 905

[1]Short ton data from 10 pp 22 23

TABLE 5 — Ore reserve estimates[1] based on 1½-percent cut-off for Missouri portion of Tri State District December 31 1947[2]

Unit	Crude ore	Recoverable concentrates	
		60 percent zinc	80 percent lead
Metric tons	24 440 400	812 065	57 740
Short tons	27 156 000	902 294	64 156

[1]Based on measured indicated and inferred ore

[2]Short ton data from 13 p 14

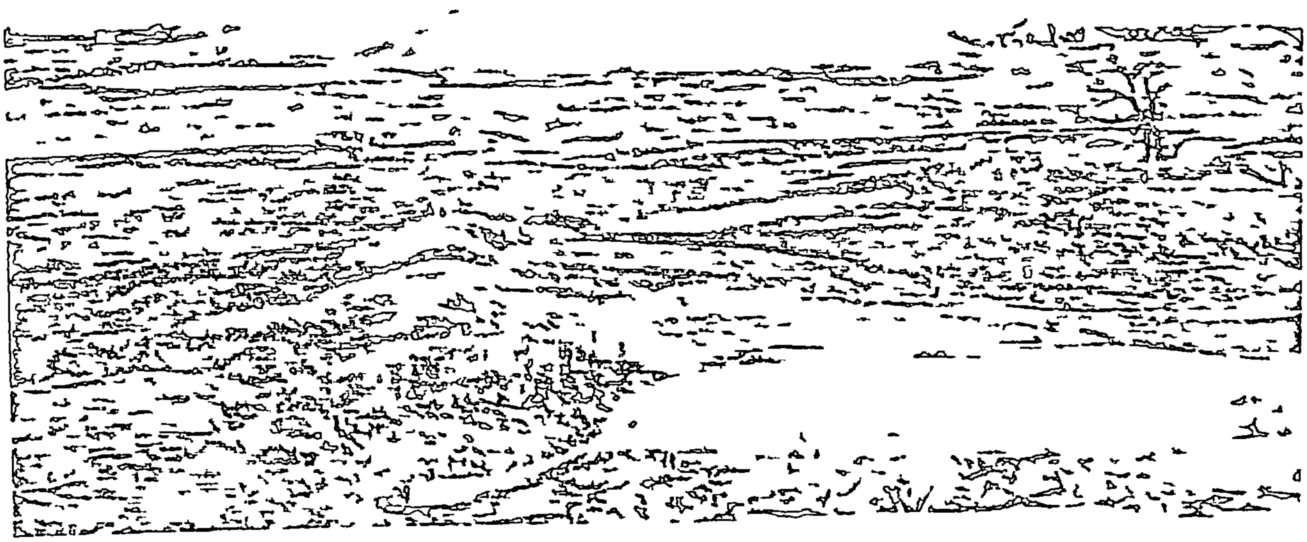


FIGURE 3 – Mine waste pile containing mixed chats

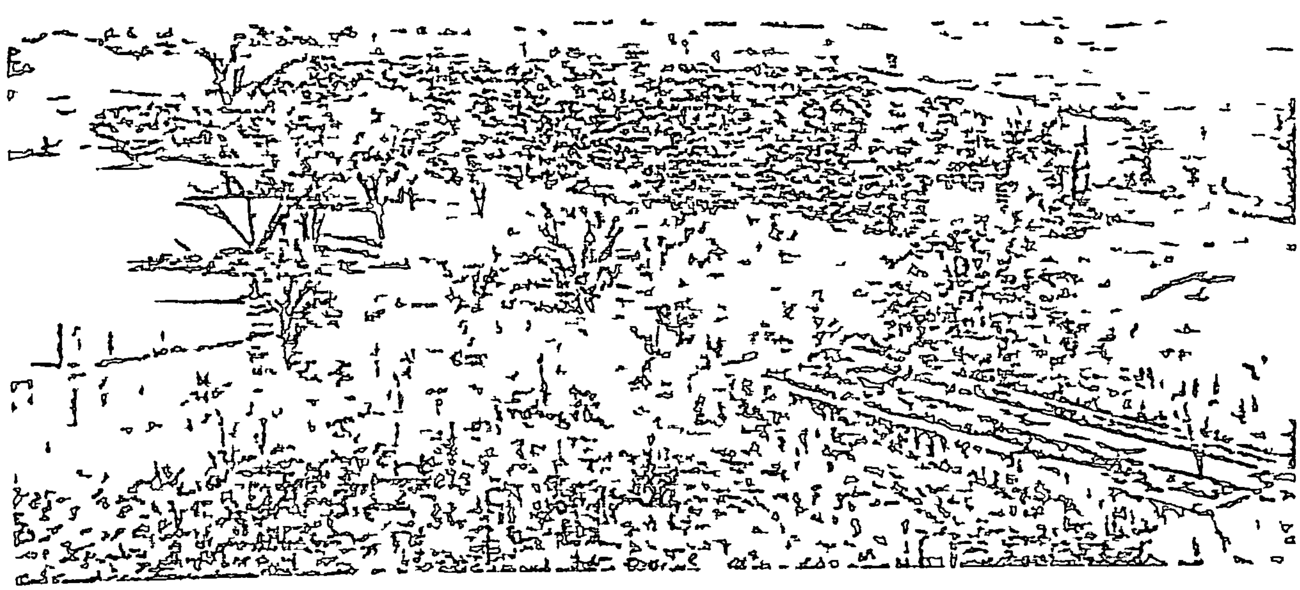


FIGURE 4 – Mine waste pile containing chats and boulders

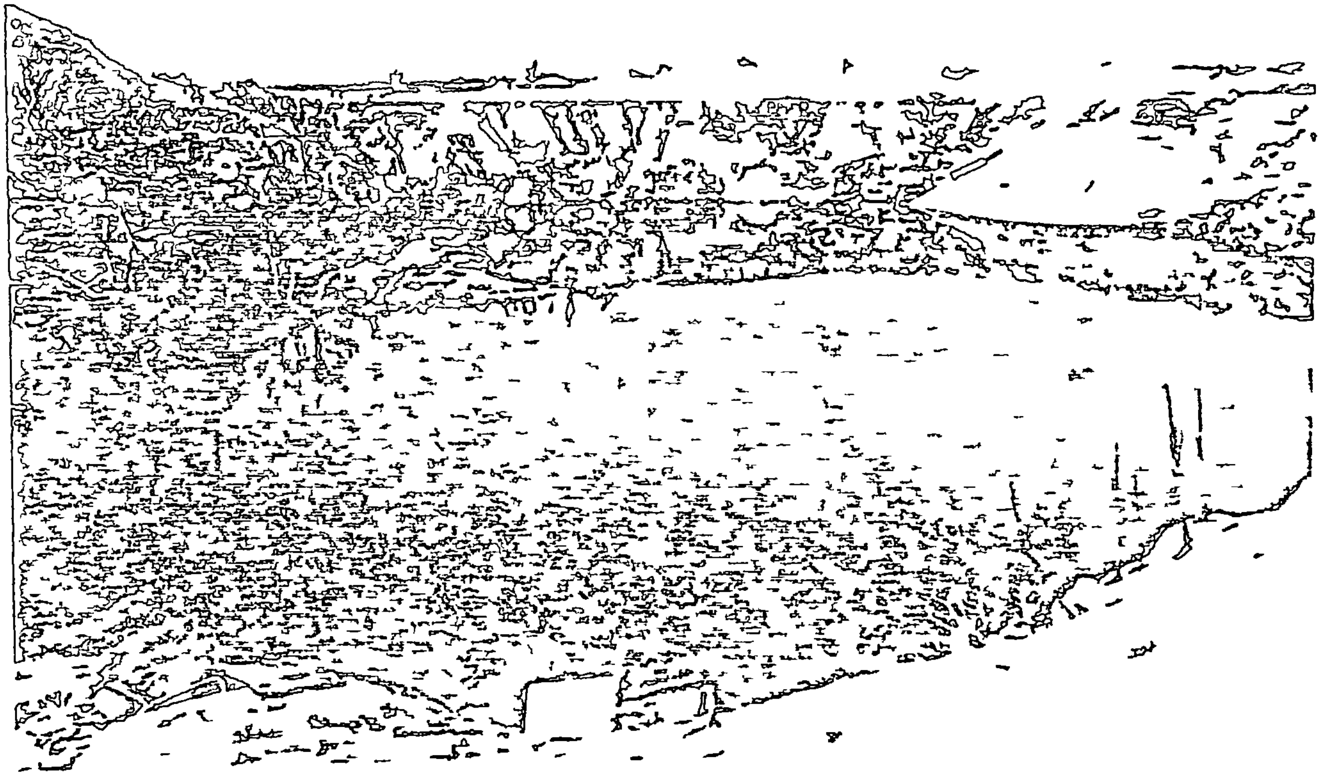


FIGURE 5 — Mine waste pile subsided below surface

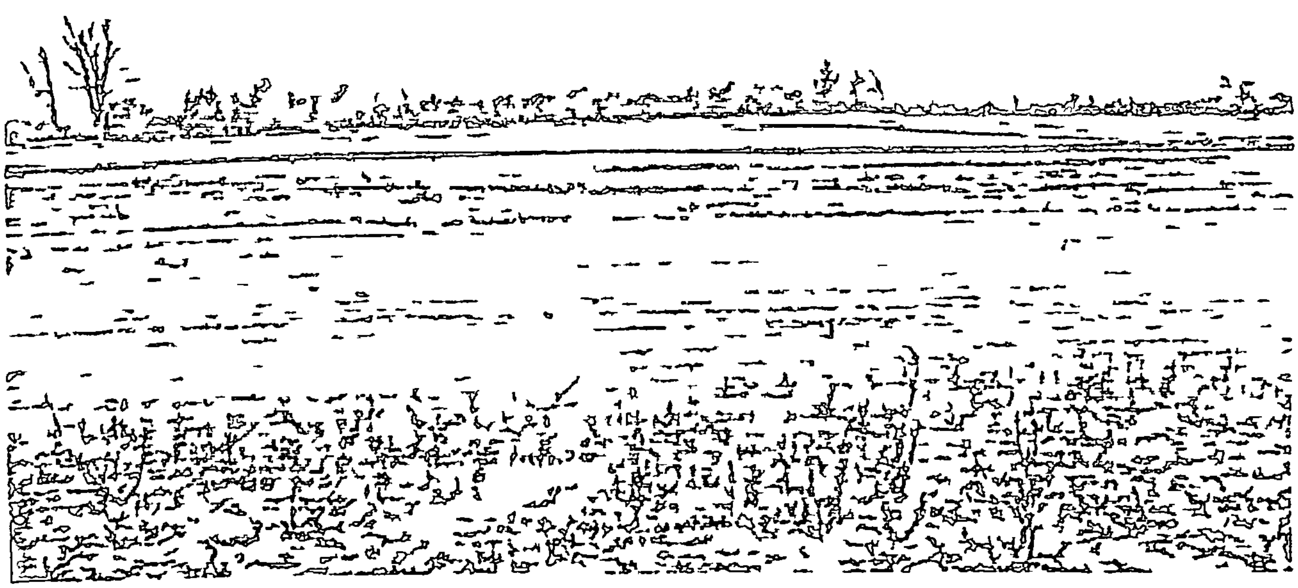


FIGURE 6 — Reclaimed mine area utilizing leveled chats

materials (17, p 25) Several smaller companies also process the mine tailings for commercial use

Estimated reserves of approximately 6,000,000 m^3 (8,000,000 yd^3), or 10,000,000 short tons, in waste products exist in the study area (15, pp 56, 60) As shown in plates 3A-D, very few large piles remain Extensive areas of scattered mounds and thin-layered "chat-flats" exist throughout the study area Some areas have been reclaimed by leveling and incorporating the remaining chats with the soils and overburden Figure 6 shows such an area reclaimed for industrial use Most waste piles and their surrounding areas are barren, except for refuse dumps, and are likely to remain in this unsightly condition Reclamation will be expensive

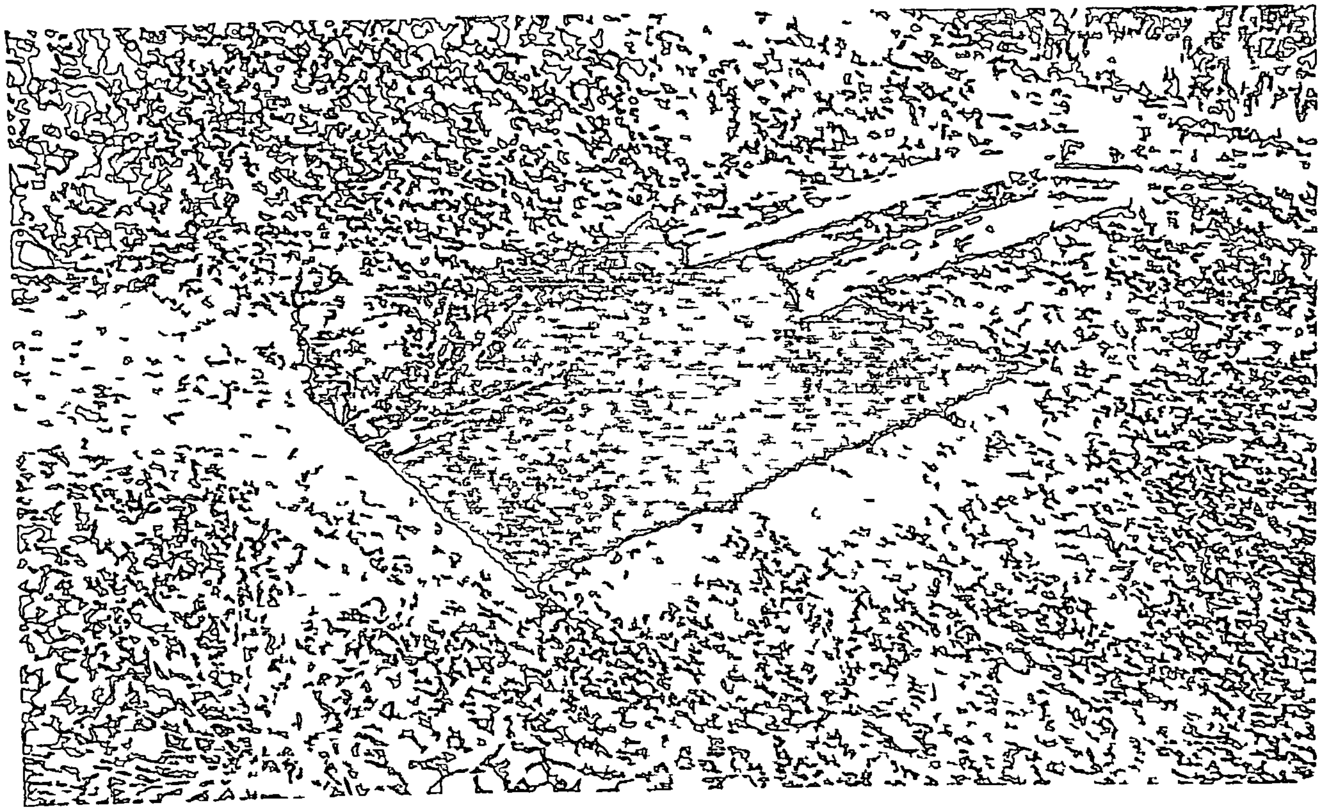
DESCRIPTIONS OF HAZARDS AND SUGGESTED METHODS OF CONTROL

The tables in this report (appendix A) indicate that many actual and potential safety hazards and environmental problems have resulted from over a century of mining in the project area Open mine shafts, subsided areas having steep, unstable slopes, and open pits containing deep pools of water exist throughout the region Damage to buildings and roads above shaft areas and underground mine workings have been reported Accidents to people and livestock frequenting or wandering into abandoned mining sites in rural areas have also occurred In addition, water-quality problems result from artesian flow of mine waters from open shafts, and rainwater runoff and seepage from tailings piles and settling ponds In the following paragraphs, typical hazards and problems are described and several methods of controlling or eliminating them are suggested

Some 323 open mine shafts have been located and described during the course of this study (table 3) Their surface expressions range from 0 9 m x 0 9 m (3 ft x 3 ft) square holes with vertical sides to 15 m (50 ft)-diameter openings with unstable, funnel-shaped slopes Figures 7, 8, and 9 illustrate typical shaft openings Depths to water level were found to be as much as 36 m (120 ft), however, some shafts were water-filled to the surface or actually having artesian flow (fig 10) Some shafts descend to dry, choked bottoms 4 5 - 18 m (15 - 60 ft) below the surface These dry-bottomed holes result from partial filling with various materials, such as mine waste-rock, junk-metal, forest debris, and assorted household trash The most hazardous sites are open shafts concealed by surrounding trees and/or other vegetation

Effective methods of closing off or, at least, safeguarding these dangerous openings are badly needed Backfilling with available tailings and mine waste-rock would provide closure and aid in reclaiming affected lands Concrete foundations, boulder piles, and chat accumulations in most cases are immediately adjacent to open shafts These materials could be used as fill It is only necessary that earth-moving machinery have access to the shaft area Although many backfilled shafts observed in the field show slumping and settling of the fill, the danger of long, vertical drop-offs has been effectively removed Figures 11, 12, and 13 depict shafts backfilled with various materials

Another method of closing a dangerous shaft is sealing, or capping, the opening at the surface Such a procedure requires competent rock around the shaft opening and some type of solid base to which a seal can be attached Open shafts with concrete collars or wood cribbings intact at the surface possess suitable bases for several types of temporary seals Metal plates welded together and anchored securely to a base form an effective closure (fig 14) Metal or wooden cross-members have been placed over a base and covered with poured concrete mixes or heavy slabs (fig 15)



FIGURF 7 — Open shaft with intact concrete collar

FIGURE 8 — Open shaft with funneling sides

FIGURE 9 — Open shaft with collapsed wood cribbing

FIGURE 10 — Artesian shaft issuing mine waters

FIGURE 11 — Closed shaft filled with rubbish

FIGURE 12 – Closed shaft backfilled with chats

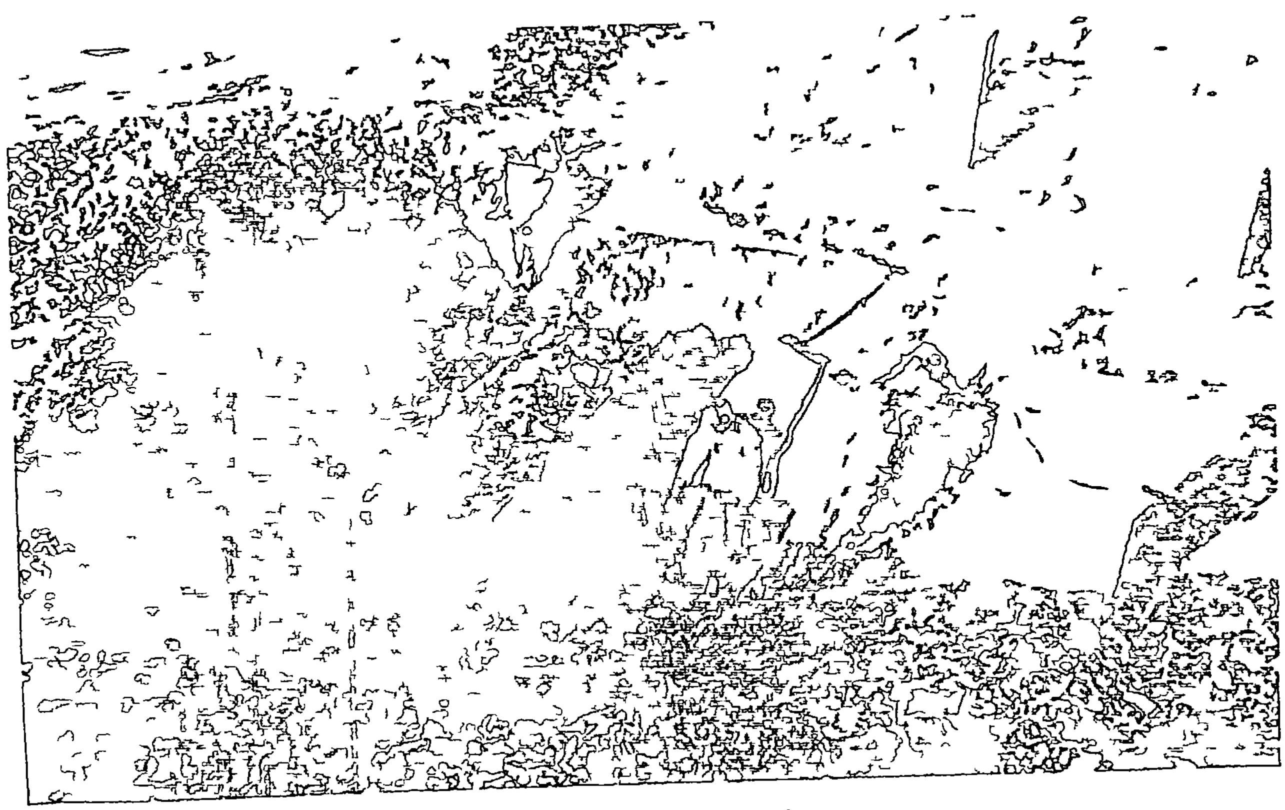


FIGURE 13 – Closed shaft backfilled with chats and concrete foundations

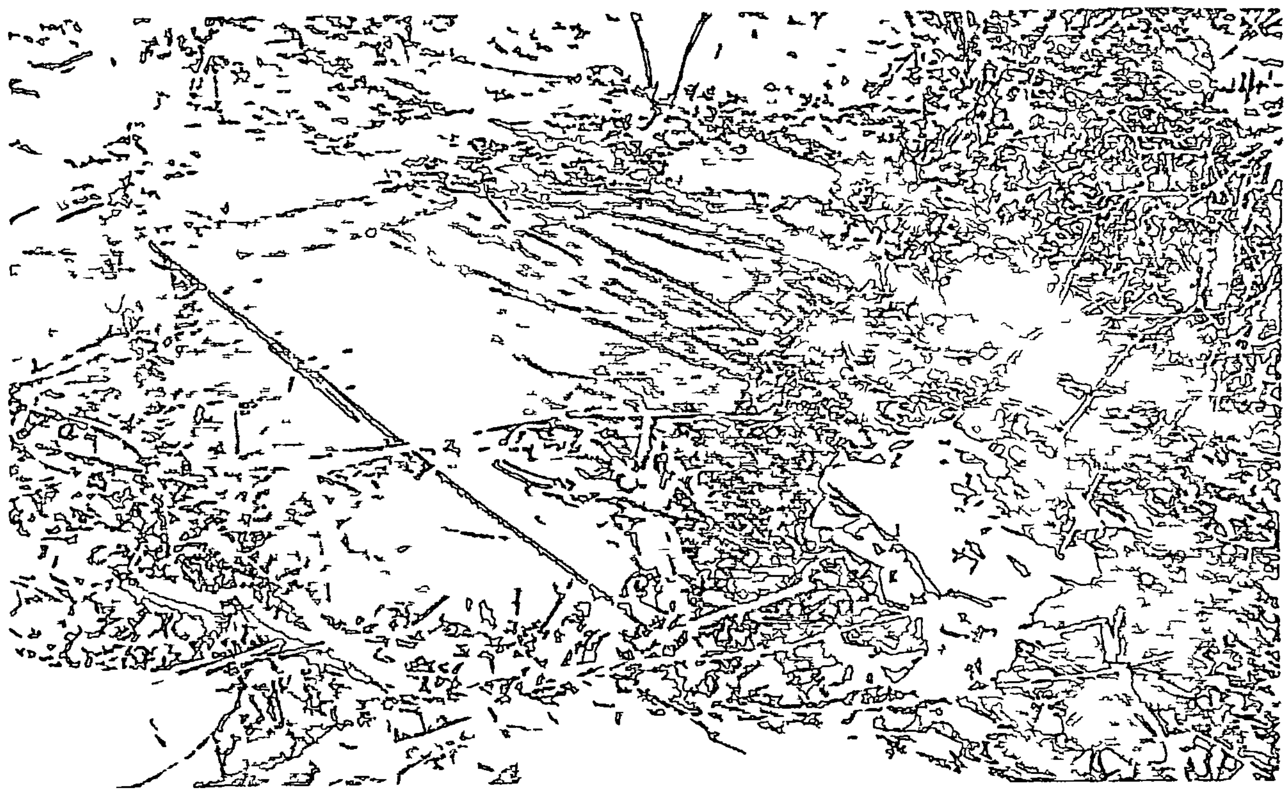


FIGURE 14 – Closed shaft protected with metal plates

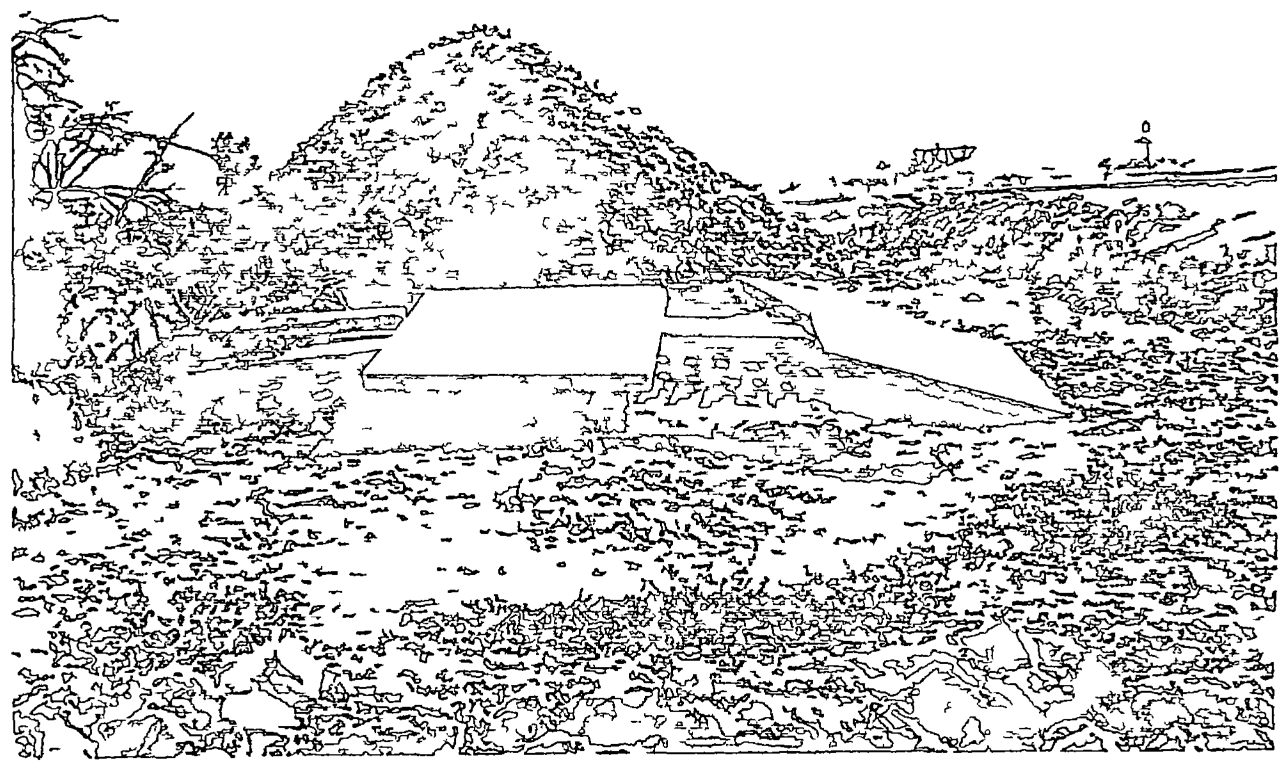


FIGURE 15 – Closed shaft protected with concrete slabs

Some open shafts lead to underground mines having considerable ore reserves In such cases, suitable procedures would be to affix a temporary cap, as shown in figure 14, or erect sturdy metal fencing around openings and post "danger" signs, a method that would serve to warn but still allow access to the mineral reserves Figures 16 and 17 show enclosures around open shafts lying above "sheet-ground" reserves in the Duenweg-Webb City-Oronogo field

In the project area, 124 subsided areas have been inventoried (table 3) They are round, oval, or elongate pits usually containing deep pools of water and having steep, unstable slopes (fig 18). The pits are 002 - 04 km^2 (5 - 10 ac) in area These collapsed areas closely follow the outlines of underground workings, evidence that weak and/or thin roof rock once capped these mines Subsidence pits are water-filled where they are directly connected to flooded underground mine workings Dry-bottomed subsidences occur where such connections no longer exist Subsidence pits have long been popular dump sites for all kinds of refuse (fig 19), a practice that has only added to the problems of water pollution and unsightly abandoned mined lands

Because water-filled pits are directly connected to the mines, backfilling the pits and plugging their connections to underground workings seems the only solution, but would require enormous amounts of fill Unfortunately mine and mill wastes adjacent to subsided areas could hardly begin to provide enough material for such attempts, hence, other economical fill materials would have to be procured

The steep slopes of dry subsidence pits could be reduced to gentler grades, thus removing the primary danger of near-vertical drop-offs Backfilling could also be attempted if sufficient fill material were available In all cases, posting of 'danger" signs would provide minimum initial safeguards The potential for future collapse of these pits into the mine workings with subsequent flooding exists

In areas where zinc and lead ores were highly concentrated, open-pit mining was employed (3, p 9), seven such sites have been inventoried (table 3) Large circular holes over 60 m (200 ft) deep and up to 240 m (800 ft) in diameter were carved out by the miners These large voids are almost completely-filled with water today, constituting dangers similar to those of flooded subsidence areas Because of their immense size and accessibility, local people regularly visit these sites for scuba-diving, swimming, and fishing (fig 20) Drownings have been reported at the famous Oronogo Circle (fig 21) since it began to fill with water after 1948 (16, p 222) People are currently aware of the inherent dangers associated with these abandoned open pits, but continue to enjoy recreational activities at these sites

Mine-related water-quality problems exist throughout the study area Many open shafts were found to have wet-weather or perennial artesian flow of mine waters to the surface. Rainwater runoff and seepage from waste piles is also common The effects of these processes have been examined (1) and some possible solutions proposed (14, 17) Stability problems arise as the downward movement of surface waters accelerates deterioration of ground adjacent to open shafts, thus promoting further collapse In addition, subsided areas experience increased widening of their perimeters as well as further steepening and undercutting of their slopes Backfilling or sealing hazardous sites would greatly reduce the damaging effects of such waters Fenced areas around open shafts should be of sufficient size to prevent fences from being undercut by gradual collapse near the tops of the shafts

FIGURE 16 – Open shaft and collapsed area safeguarded with metal fencing

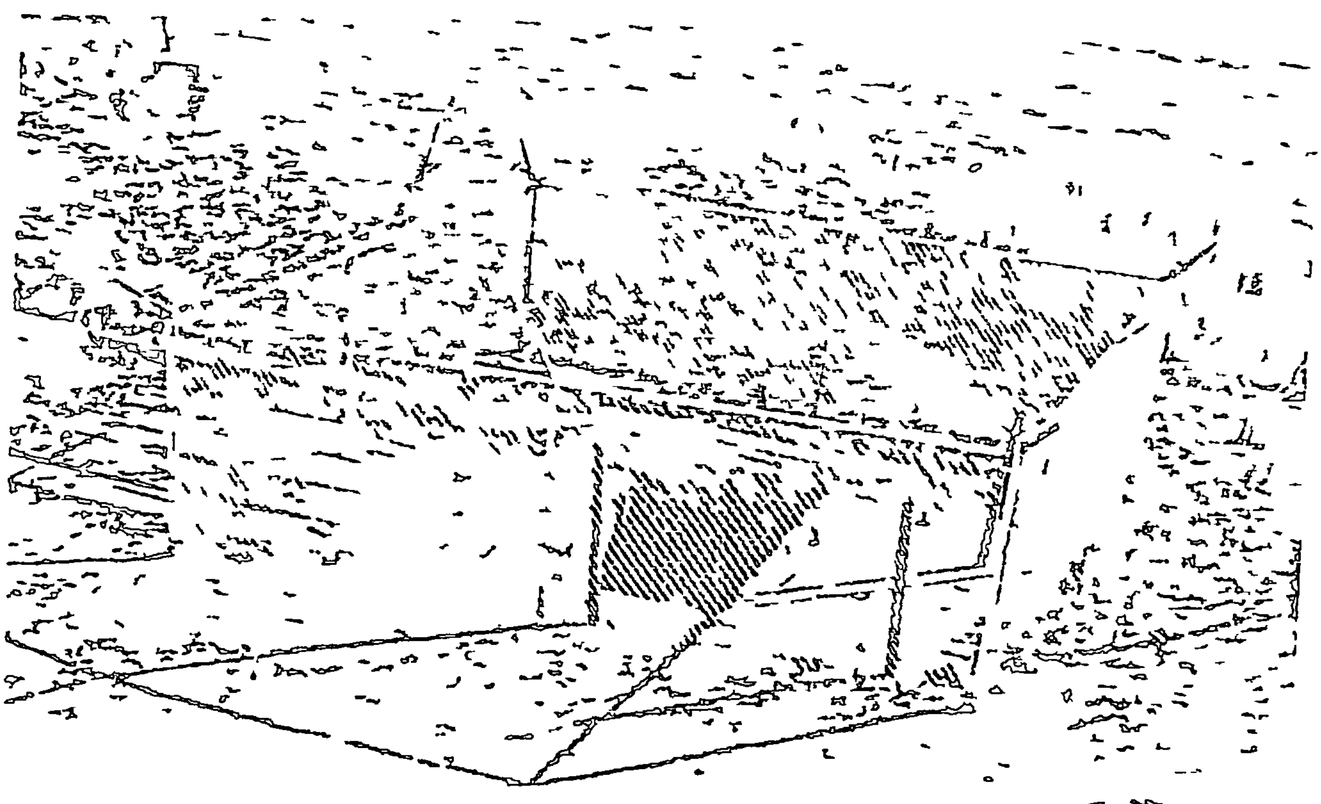


FIGURE 17 – Open shaft safeguarded with metal fencing

FIGURE 18 — Subsidence pit filled with water

FIGURE 19 — Subsidence pit filled with water and rubbish

FIGURE 20 – Open pit filled with water and used as recreational area

FIGURE 21 – Oronogo Circle famous open pit now filled with water

subsidence occurred on June 1 1982, in the parking lot of the St John's Regional Medical Center (site number 27-33-15-3) The resulting hole was 20 m (60 ft) deep and filled with water to within 6 m (20 ft) of the surface The oval-shaped surface outline, measuring 3 x 6 m (10 x 20 ft), is shown in figure 24 A fill of rock and concrete mix has temporarily sealed the opening at this site (fig 25) It is apparent that this area holds a high potential for future, subsidence-related problems

There is an extensively mined area, known locally as Chitwood, at the northwest edge of Joplin (secs 3 and 4, T 27 N , R 33 W , secs 32 and 33, T 28 N , R 33 W , Joplin West Quadrangle) Sixteen open shafts and three subsidence pits were observed The majority of these openings are either filled with water to the surface or have artesian flow Some 'warning' and "danger" signs have been posted, however, public access is not controlled and therefore the entire area is quite hazardous because it is near populated sections of Joplin A similar situation exists just west of Joplin, near Central City, where 16 water-filled open shafts were found (secs 5 and 6, T 27 N , R 33 W) At site number 27-33-5-1, major cave-ins in the roadbed of West 7th Street (old U S 66) resulted from collapsing mine workings below The Missouri Highway and Transportation Department carried out large-scale repairs during the 1940's, 1963, and 1981

Another locality in the Joplin West Quadrangle was found to contain 25 hazardous sites that revealed recent collapse features (secs 19 and 20, T 27 N , R 33 W , sec 24, T 27 N , R 34 W) The surface edges of the subsidence pits are badly undercut by recent caving, and the open shafts show fresh collapse in their loosely consolidated rock walls In cross-section, the openings are dome-shaped Because the area is private property, access is somewhat controlled, however, the posting of "danger' signs would be an additional, economical safeguard

In the Carl Junction Quadrangle, two areas are notable for their dense concentration of mine-related hazards The first area, just southwest of the city of Carl Junction (sec 7, T 28 N , R 33 W), contains 15 open shafts and 5 subsidence pits The shafts are in advanced stages of collapse, the subsidence pits, up to 30 m (100 ft) in diameter, are water filled Public access to these sites is uncontrolled The second area, southwest of the town of Waco, adjacent to the Missouri-Kansas border (secs 14, 15, 22, and 23, T 29 N , R 34 W), is honeycombed with 28 open shafts and 23 subsidence pits, all of which have incompetent Pennsylvanian strata in their upper walls These weak surface layers of rock are largely responsible for the extensive collapse throughout this area Water quality is also a problem here Enormous amounts of rubbish are being dumped in and about the water-filled subsidence pits Reddish-brown mine waters are spilling onto the surface from several shafts with artesian flow It is expected that mine-related problems (surface stability, open shafts, and water quality) near Waco will continue and intensify

Field observations disclosed more hazardous sites (242) in the Webb City Quadrangle than in the other three quadrangles combined (227) Nearly all 242 sites are within two distinct northwest-southeast trends One trend, 3 2 km (2 mi) long and 1 6 km (1 mi) wide, is near the towns of Alba, Purcell, and Neck City, the other, 8 km (5 mi) long and 2 4 km (1 5 mi) wide, extends from Prosperity to Ononogo, and includes the ground between Webb City and Carterville

Twelve subsidence pits and 11 open shafts were discovered in the vicinity of Alba, Purcell, and Neck City (secs 8, 9, 10, 15, and 16, T 29 N , R 32 W) The caving walls of the openings are composed of loosely consolidated Pennsylvanian shales and sandstones

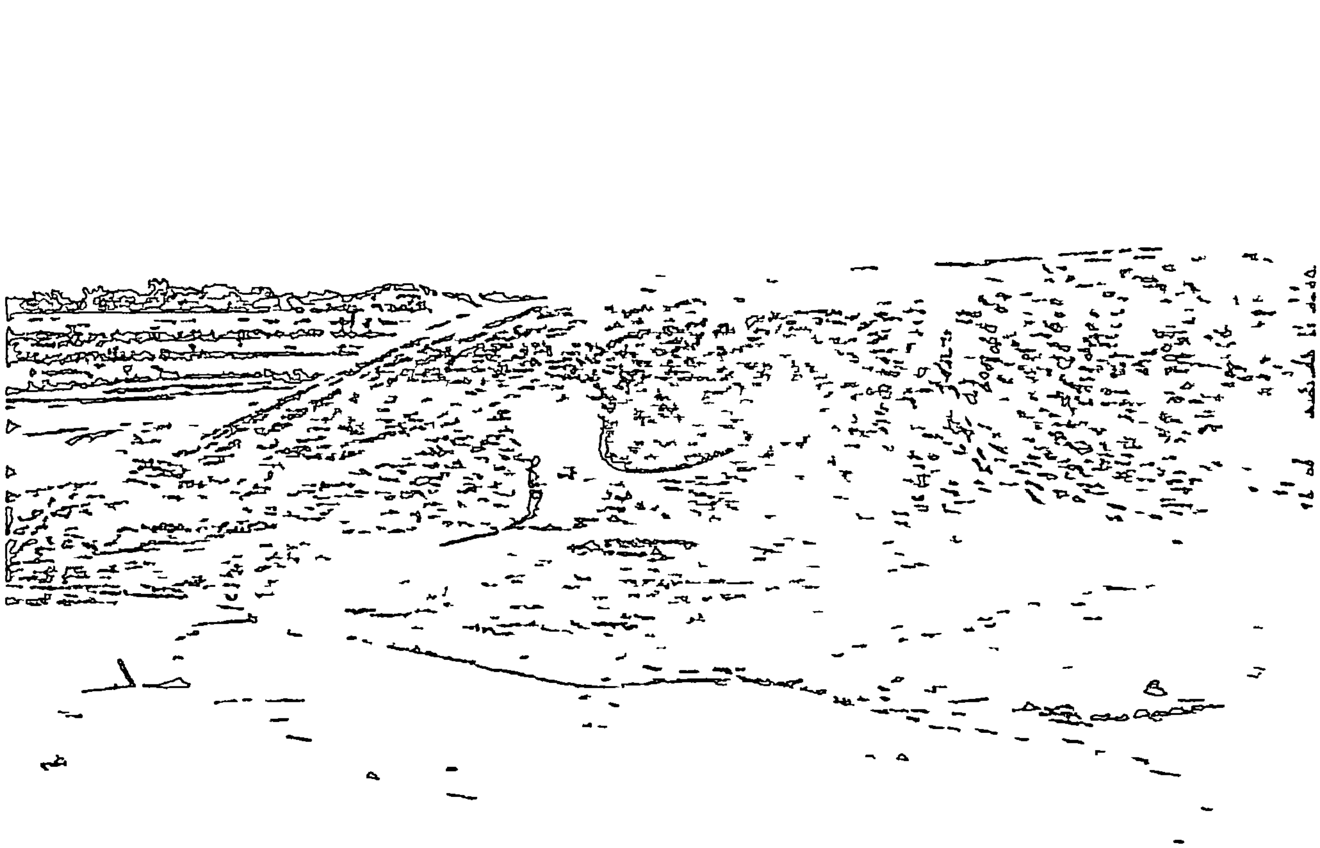


FIGURE 26 – Collapsed area within chat pile

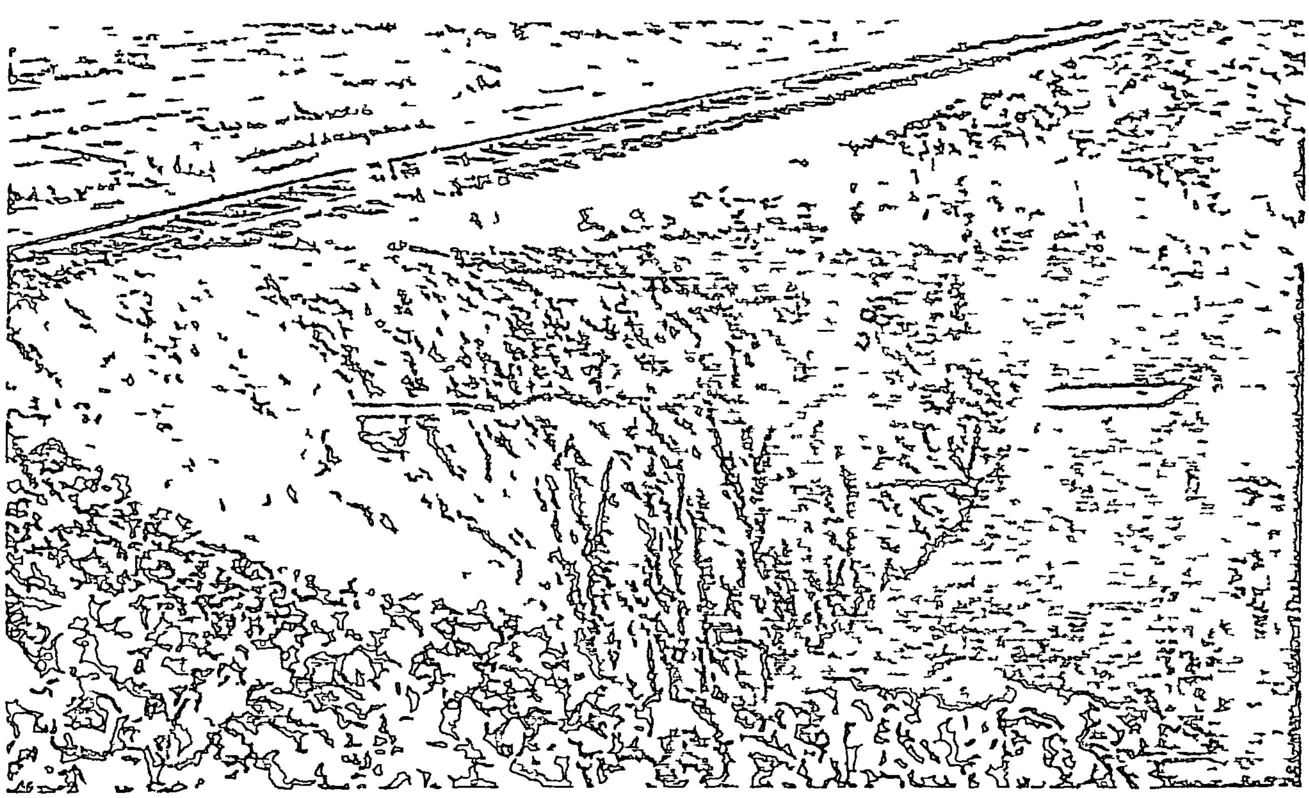


FIGURE 27 – Collapse at top of open shaft encroaching on railroad

Recent collapse is evident at many sites Trash dumps were observed adjacent to those pits and shafts that are easily accessible Both stability and environmental conditions in this area are likely to degrade further

Fourteen hazardous openings, characterized by collapsing beds of incompetent Pennsylvanian rock in their steep, caving sides, are present in a very unstable tract of land (NW¼ SW¼ sec 31, T 29 N , R 32 W), just east of the renowned Oronogo Circle Depths to water level in these holes range from 4 5 - 15 m (15 - 50 ft) Because of their proximity to the town of Oronogo, these sites should be backfilled or fenced to provide some degree of public protection

A total of 196 hazardous sites (141 open shafts and 55 subsidence pits) were found in an area extending 3 2 km (2 mi) northwest-southeast on either side of Webb City and Carterville (secs 6, 7, 8, 17, 18, 20, and 21, T 28 N , R 32 W , secs 1 and 12, T 28 N , R 33 W) The land between these two cities is particularly crowded with dangerous mine openings, there are 87 hazardous sites in an area of approximately 2 km^2 (500 ac) In addition, refuse dumps are abundant, and several shafts with artesian flow are discharging reddish-brown mine waters into Mineral Branch (known locally as "Ben's Branch"), a tributary of Center Creek Only a comprehensive reclamation program will improve such conditions Another 109 hazardous sites were seen outside the two cities The most seriously affected areas are near Center Creek (sec 6, T 28 N , R 32 W) and Prosperity (sec 21, T 28 N , R 32 W), where subsidence has caved in 0 014 - 0 016 km^2 (3 5 - 4 ac) tracts of surface ground (site numbers 28-32-6-16 and 28-32-21-24) Public access to hazardous sites in these regions is largely uncontrolled Fencing mine openings and posting "danger" signs would provide inexpensive, temporary safeguards

A final consideration with respect to future stability problems concerns the potential for reopening of backfilled shafts Funnel-shaped depressions in tailings piles result from gradual settling and subsidence of fill materials into shafts beneath the piles (fig 26) Most backfilled shafts in the study area also show slump features at the surface (figs 11 and 13) This same deterioration process is occurring around tops of open shafts Sloughing of easily eroded soils and incompetent rock layers has caused many open shafts to expand laterally at the surface Figure 27 illustrates a collapsing shaft encroaching on a nearby railway line, thereby posing dangers to personnel and equipment Caving and subsidence at shaft sites, both open and closed, will continue to be a persistent problem

SUMMARY OF LAWS APPLYING TO ABANDONED METAL-MINING AREAS

The following is a compendium of federal and Missouri laws pertaining to abandoned metal mines and lands The federal surface mining laws apply primarily to coal mining, however, sections are included which address the problems of non-coal mining It should be noted that funds will be used for non-coal problems only if public health and safety considerations are endangered This allow the Governor to request that moneys be used from the trust fund established for this purpose The Abandoned Mine Reclamation Fund is administered by the Secretary of the Interior through the Office of Surface Mining All coal reclamation projects have priority to draw on the fund As coal reclamations are completed, the remaining money in the fund could be used for non-coal reclamations Continued research for effective and adequate reclamation of metal-mining areas could greatly enhance the prospects of using the fund as coal reclamations are concluded

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Roarke Diggings (west shaft)	27-32-30-1	SE-SE SE-SW-NE-SE Sec 30-27N -32W Joplin East Quad Newton Co , Mo	Small shaft with rock-walled sides 30' deep	Ample chat piles in the vicinity would provide back-fill for the open shaft
Roarke Diggings (central shaft)	27-32-30-2	SW-SW-SE-NE-SE Sec 30-27N -32W Joplin East Quad Newton Co , Mo	Small shaft with rock-walled sides, 20' deep	Ample chat piles in the vicinity would provide back-fill for the open shaft
Roarke Diggings (east shaft)	27-32-30-3	SW-SW-SE-SE-NE-SE Sec 30-27N -32W Joplin East Quad Newton Co , Mo	Small shaft with rock-walled sides, 30' deep	Ample chat piles in the vicinity would provide back-fill for the open shaft
Roarke Diggings (open pit)	27-32-30-4	SW-SW-SE-NE-SE Sec 30-27N -32W Joplin East Quad Newton Co , Mo	Large open pit, 100' long (north-south direction), 150' wide (east-west direction) 20' deep, steep-sided walls in places	Since land lots are being sold in this area, the open pit should be graded and smoothed out Ample fill material in the vicinity
Union Mine (west shaft)	28-32-28-1	E2-SE SE-SE Sec 28-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open and caving, 50' deep to a dry bottom, opening is 4' x 4', rock-walled, no cribbing visible very small tailings dump thick foliage surrounds site, small waste pile adjacent to shaft	Shaft could be filled with forest debris which is available nearby Since there is a dry bottom to the shaft, back-filling would do an adequate job of closing the hazard

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Gibson Mine	28-32-28-2	S2-N2-SE-SW Sec 28 28N -32W Joplin East Quad Jasper Co , Mo	Shaft was originally 185' deep is now 60' deep to water level, 4' x 6' cribbing is intact, large chat piles in area, and barbed wire fencing at one side of shaft Opening is adjacent to a large natural sinkhole hazard has limited access, is on private property with owner's home a short distance from shaft	Since area is private property, access is limited fencing and/or a wooden cover would serve as an adequate temporary closure Ample boulders and chats are available for backfilling
Nowata Mine	28-32-28-3	NE-NE-SW-SE-SW Sec 28-28N -32W Joplin East Quad Jasper Co , Mo	Shaft was originally 190' deep now 50' deep to water level, opening is covered with a wood grate and surrounded by barbed wire large chat piles This shaft is a USGS water gauging station, has limited access private property with owner's home a short distance from shaft area	Concrete pad poured over the existing wood grate would serve as an effective seal Plenty of fill material in vicinity area is accessible to heavy machinery
Ten O'Clock Mine (northeast shaft)	28-32-28-4	SE-NE-NE-NE-SW Sec 28-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open, lined by steep piles of waste rock on north side, 3' x 3' cribbing intact, hazard easily accessible no vegetation present	Ample chat piles in area could be used for backfilling Opening is cribbed with wood and provides a crude base for laying a seal over shaft

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Milan Mine (Florine shaft)	28-32-28-10	NE-SW-SE-NW Sec 28-28N -32W Jóplin East Quad Jasper Co , Mo	Shaft is open originally 201' deep, now 65' deep to water level, 3' x 5' wood cribbing remains but is quickly collapsing, site is somewhat foliated large boulder and chat piles adjacent to shaft hazard is easily accessible being adjacent to a jeep trail This shaft is a USGS water gauging station	The boulder piles in area could quickly back-fill this shaft - the collapsing cribbing may close this opening naturally Fencing would be a temporary pre-caution since site is very accessible
Milan Mine (west shaft)	28-32-28-11	W2-W2-W2-SE-NW Sec 28-28N -32W Joplin East Quad Jasper Co Mo	Shaft is open with 3' x 3' wood cribbing intact 40' deep to water level hazard is easily accessible being adjacent to jeep trail and miner's drainage canal some foliage in area	This shaft could be back-filled easily with nearby chats Fencing would be a low-cost temporary option Lack of collapse at surface could make a wood or metal cover over top of cribbing another good option
Jasper County Land & Mining Co Mine (north shaft)	28-32-28-12	N2-N2-SE-SW-NW Sec 28-28N -32W Joplin East Quad Jasper Co Mo	Shaft is open originally 132' deep, now 40' deep to water level located on NW slope of a large open pit, opening is 3' x 3' and wood-cribbed easily accessible via jeep roads	Cribbing is intact to surface and no collapse evident - thus, a wood, metal or concrete cover using the square cribbing as a base would effect a good seal
Goodrich Mine (east shaft)	28-32-28-13	SE-SE-NE-NW Sec 28-28N -32W Joplin East Quad Jasper Co Mo	Shaft is open, originally 175' deep now 50' deep to water level, entrance lies in a foliated area alongside a large chat pile wood-cribbed opening is in a state of minor collapse	Plenty of chat for fill material nearby Site is very accessible to heavy machinery

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Goodrich Mine (west shaft)	28-32-28-14	SW SE-NE-NW Sec 28-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open originally 175' deep, now 60' deep to water level, opening lies between large chat piles and vegetation, cribbed entrance has minor collapse	Ample chats for back-filling; good access for heavy ma chinery
Mt Ararat Mine	28-32-29-1	N2-SE-NE-NE Sec 29-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open, originally 133' deep, now 40' deep to water level, opening is not visible due to dense vegetation and trees growing in and around shaft, some collapse is evident at opening	Ample chat and boulders adjacent to shaft for back-filling Area is marginally accessible to heavy machinery
Mary C Mine	28-32-29-2	SW-SW-NE-SE-NE Sec 29-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open 40' deep to water level, dense vegetation near opening, east-west fence line runs past shaft on north side large chats lie on SE side	Poor access to shaft area for heavy machinery Ample fill material adjacent to site Fencing not too practical around this shaft since loose waste rock is too close to opening
St Anthony Mine	28-32-29-3	N2-NE-NE-SE Sec 29-28N -32W Joplin East Quad Jasper Co Mo	Shaft lies 100' SW of a shallow open pit, opening is slightly collapsed at surface and measures 3' x 3' at wood cribbing, some chats and boulders nearby	Back-filling would probably be the best method for closure Collapse around opening would not permit fencing to offer a long-term remedy Ample fill material in area and good access exists for heavy machinery

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Coahuila Mine (northwest shaft)	28-32-33-5	SE-SW-NE-SW-NE Sec 33-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open and 50' deep to water level, present opening is quite small due to collapse - about 1 foot square Shaft is rock-walled and caving badly	Some more back-filling along with the natural collapse should close off this hazard
Coahuila Mine (central shaft)	28-32-33-6	C-W2-E2-W2-E2 Sec 33-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is open and 80' deep to water level, badly collapsing ground adjacent to shaft opening is 6 ft square, pentagonal shape of wire-fencing surrounds the site	Site is very dangerous despite the fencing, further safeguard is needed such as back-filling or plugging
Gussie K Mine (south shaft)	28-32-33-7	SE-SW-SW-NE-SW Sec 33-28N -32W Joplin East Quad Jasper Co , Mo	Open pit with water measures 30' in diameter shaft could possibly be open below the water Area is presently protected by a tall wire fence completely surrounding the site water depth is at least 20' large chat piles are nearby	Site is well protected at this time, however, a permanent solution should be proposed for the future possibly draining the pit and then back-filling
Melrose Mine (south workings)	28-32-33-8	S2-NW-SE-SE-NW Sec 33-28N -32W Joplin East Quad Jasper Co Mo	Shaft is open and 70' deep to water level, opening measures 4' x 6' and is wood-cribbed to the surface metal fencing surrounds the site, large chat piles and concrete foundations are adjacent to the shaft	This site is protected temporarily by the fencing a further safeguard would be a metal or concrete cover, or plug, over the entrance

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Fidelity Mine	28-32-34-8	C-S2-SE-SW-SW Sec 34-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is well-hidden amidst a dense thicket of foliage at the NW end of a huge chat pile, opening is collapsed at surface to 15' diameter, 4' x 6' wood cribbing visible 20' below surface	Huge chat pile lies adjacent to shaft site Back-filling would be a good corrective measure since access is excellent for the necessary heavy machinery
Thanksgiving Mine (south shaft)	28-32-34-9	N2-NE-NE-SW-NW Sec 34-28N -32W Joplin East Quad Jasper Co , Mo	Shaft is well-hidden, lying within a thicket of trees adjacent to gravel road opening is collapsing, 10' diameter at surface	Shaft is near road and could be fenced and/or filled easily if the trees in the area were removed
Thanksgiving Mine (central shaft)	28-32-34-10	S2-SE-SE-NW-NW Sec 34-28N -32W Joplin East Quad Jasper Co , Mo	6' x 6' wood cribbing remains intact to the surface shaft is 50' deep to water level	Shaft has a huge chat pile adjacent to it, wood cribbing provides a base for a metal or wood cover for sealing, fencing would also be a good option in this case Access is good for any type of machinery
Appleknocker Mine (south shaft)	28-32-34-11	NE-NW-SW-SW-NW Sec 34-28N -32W Joplin East Quad Jasper Co Mo	Shaft is open and rock-walled with some caving near the surface, originally 185' deep, now 50' deep to water level, shaft opening is well-hidden due to thick vegetation	Plenty of boulder-size rock lies immediately south of shaft Access for heavy vehicles to back-fill is marginal

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Underroof Mine	27-33-4-1	NE-NW-SE-NE-NE Sec 4-27N -33W Joplin West Quad Jasper Co Mo	Shaft is open, 10' in diameter, filled with water junk metal and debris Chat flats in area	Back-filling recommended fill material would have to be hauled in, good access for heavy machinery
Condor Mine	27-33-4-3	C-E2-E2-NE-NW-NW Sec 4-27N -33W Joplin West Quad Jasper Co , Mo	Shaft is open, 10' in diameter, 5' to water level, floating vegetation in shaft Chat and boulders remain	Ample chats in vicinity for back-filling purposes
Portland Mine	27-33-4-4	E2-NE-NE-NW-NW Sec 4-27N -33W Joplin West Quad Jasper Co , Mo	Shaft is open 15' in diameter, water-filled Concrete foundations drifting toward shaft	Old foundations and nearby chats would provide back-fill material
Baltimore Mine	27-33-4-6	E2-SE-NW-NW-NW Sec 4-27N -33W Joplin West Quad Jasper Co , Mo	Shaft is open, 25' in diameter, very steep, loose near opening, 20' deep to water level	Boulder and chat piles in area can be used for back-filling
Ramage Mine (east shaft)	27-33-5-2	C-W2-W2-SE-NW-SW Sec 5-27N -33W Joplin West Quad Jasper Co Mo	Shaft is open, 30' diameter pool of water within a caving pit, adjacent to chat/boulder piles	Large chat/boulder piles at site should provide plenty of back-fill material
Ramage Mine (west shaft)	27-33-5-3	C-SW-NW-SW Sec 5-27N -33W Joplin West Quad Jasper Co Mo	Shaft is open, 20' diameter pool of water within a caving pit, shaft possibly open below water	Large chat/boulder piles at site should provide plenty of back-fill material

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Gimlet Mine (south shaft)	27-34-24-10	C-S2-S2-S2-NE-SE Sec 24-27N -34W Joplin West Quad Newton Co Mo	Shaft is open rock-walled, collapsing and 30' deep to water level	Access is controlled to this area due to private property, however, ample chats are available for back-fill material Posting danger signs would also be a good safeguard
Gimlet Mine (southeast shaft)	27-34-24-12	S2-SW-SE-NE-SE Sec 24-27N -34W Joplin West Quad Newton Co , Mo	Shaft is open, rock-walled, collapsing, and 30' deep to water level	Access is controlled to this area due to private property, however, ample chats are available for back-fill material Posting danger signs would also be a good safeguard
Cock Robin Mine	28-33-32-1	SW-SW NW-NE-SE Sec 32-28N -33W Joplin West Quad Jasper Co , Mo	Shaft is open, 12' in diameter artesian, shaft area is foliated Chat and boulder piles remain	Cyclone fencing, posting 'DANGER" signs and back-filling is recommended
Nickolsville Mine	28-33-32-2	C-E2-E2 SE-NW-SE Sec 32-28N -33W Joplin West Quad Jasper Co , Mo	Shaft is open, 10' in diameter, 12' deep to water level concrete foundations are being undercut by sloughing Boulder and chat piles remain	Nearby chat piles can be used for back-fill material
Chicago Consolidated Mine (north shaft)	28-33-32-3	C-W2-W2-SW-SW-NE-SE Sec 32-28N -33W Joplin West Quad Jasper Co , Mo	Shaft is open, fenced, 12' in diameter, water-filled to top, fences sloughed	Nearby chat piles can be used for back-fill material

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Crackerjack Mine	28-33-33-5	SW-NE SE-SW-SW Sec 33-28N -33W Joplin West Quad Jasper Co Mo	Shaft is open, 12' in diameter, artesian Boulders and chat piles remain	Cyclone fencing, posting "DANGER" signs, and back-filling is recommended
Pralin Mine	28-33-33-6	C-W2-SW-SW-SE-NW Sec 33-28N -33W Joplin West Quad Jasper Co , Mo	Shaft is open, 15' x 25', 12' deep to water level, concrete collar undercut by sloughing and collapse Boulders and chat piles remain	Nearby chat piles can be used for back-fill material
McBride Mine	28-33-33-8	NE-NW-SW-SE-NW Sec 33-28N -33W Joplin West Quad Jasper Co Mo	Shaft is open, 6' x 12', concrete collar intact, was originally 90' deep, now 6' deep to water Boulders, chat piles and concrete foundations remain in area	Cyclone fencing, posting "DANGER" signs, and back-filling is recommended
Trimore Mine	28-33-33-9	SE-SE-NW-SE-NW Sec 33-28N -33W Joplin West Quad Jasper Co Mo	Shaft is open, 15' diameter, originally 100' deep, now 10' deep to water, sloughing beneath concrete collar Boulders, chat piles and concrete foundations remain	All mining waste (boulders, chats, concrete) in area can be used for back filling

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Barnsdall #2 Mine (south shaft)	29-34-22-16	W2-SE-NW-SE-NE Sec 22-29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open, 6' in diameter water-filled	Nearby chat and boulder piles can be used for back-fill material
Pyramid Mine (south shaft)	29-34-23-1	C-N2-NE-NW-NE Sec 23-29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open, 12' in diameter water-filled, artesian	Boulder and chat piles in area should provide enough back-fill material, access to hazard is controlled due to private property
Allegheny-Western Mine (central shaft)	29-34-23-3	NE-NE-NW-NW-NE Sec 23 29N -34W Carl Junction Quad Jasper Co Mo	Shaft is open, 12' in diameter, pool artesian, brown water Boulders, chat flats and concrete foundations remain	All mining waste (boulders, chats, concrete) in area can be used for back-filling
Allegheny-Western Mine (south shaft)	29-34-23-5	C-N2-SE-NW-NW-NE Sec 23 29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open 12' in diameter 6' deep to water level, partially junk-filled Boulders, chat flats, and concrete foundations remain,	Boulder and chat piles in area should provide enough back-fill material access to hazard is controlled due to private property
Freehold #3 Mine (northeast shaft)	29-34-23 6	N2-NE-NE-NE-NW Sec 23-29N -34W Carl Junction Quad Jasper Co Mo	Shaft is open 8' in diameter ~~artesian~~, brown water Concrete foundations chat flats and boulders remain	Nearby chat and boulder piles can be used for back-fill material
Freehold #3 Mine (northwest shaft)	29-34-23-8	NW NW-NE NE-NW Sec 23-29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open 12' in diameter water-filled, coalesced with west subsidence Concrete foundations chat flats, and boulders remain	All mining waste (boulders chats concrete) in area can be used for back-filling

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Freehold #3 Mine (west shaft)	29-34-23-10	SW-NW-NE-NE-NW Sec 23 29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open, 25' in diameter water-filled caving Concrete foundations chat flats, and boulders remain	Ample fill material in vicinity good access for heavy earth-moving machinery
Freehold #3 Mine (southwest shaft)	29-34-23-11	NW-SW-NE-NE-NW Sec 23-29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open, 10' in diameter, water-filled Concrete foundations, chat flats, and boulders remain	Boulder and chat piles in area should provide enough back-fill material, access to hazard is controlled due to private property
Tulsa-Pittsburg #1 Mine (north shaft)	29-34-23-12	SW-NW-NW-SE-NW Sec 23-29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open, 10' in diameter 6 deep to water level Pennsylvanian shales caving into hole Chat flats and boulders remain	Nearby chat and boulder piles can be used for back-fill material
Tulsa-Pittsburg #1 Mine (south shaft)	29-34-23-13	NW-NW-SW-SE NW Sec 23 29N -34W Carl Junction Quad Jasper Co Mo	Shaft is open, 20' in diameter water-filled, Pennsylvanian shales caving into hole Chat flats and boulders remain	Ample fill material in vicinity, good access for heavy earth-moving machinery
Tulsa-Pittsburg #1 Mine (central shaft)	29-34-23-15	C-SE-NE SW-NW Sec 23 29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open 10' in diameter 6' deep to water level Pennsylvanian shales sloughing into hole Chat flats and boulders remain	Nearby chat and boulder piles can be used for back-fill material
Tulsa-Pittsburg #1 Mine (west shaft)	29-34-23-16	W2-SE-NE-SW-NW Sec 23-29N -34W Carl Junction Quad Jasper Co , Mo	Shaft is open, 6' in diameter, 10' deep to water level Pennsylvanian shales visible in sides of hole Chat flats and boulders remain	Boulder and chat piles in area should provide enough back-fill material, access to hazard is controlled due to private property

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
After Glow Mine (south shaft)	28-32-6-7	C-N2-NW-SE-SW Sec 6-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open ano measures 15' in diameter at surface, caving concrete collar 50' deep to water level	All mining waste (chats boulders concrete) in area can be used for back-filling
After Glow Mine (north shaft)	28-32-6-8	C-N2-S2-N2-SW Sec 6-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open and caving at surface, 30' in dia meter hole is water-filled	Ample fill material in vicinity, good access for heavy earth moving machinery
Bull Dog Mine (east shaft)	28-32-6-9	SW-NE-SW-SW-SW Sec 6-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open 15' in diameter and 30' deep to water level concrete collar is caving and is badly undercutting boulder pile at east side	Steep caving sides make fencing a temporary safeguard, back-filling is recommended
Bull Dog Mine (west shaft)	28-32-6-10	NE-SW-SW SW-SW Sec 6-28N -32W Webb City Quad Jasper Co Mo	Shaft is 40' in diameter with steep, caving sides 25' deep to trash fill	Back-filling recommended, nearby chat/boulder piles can be used for fill material
Church & Company Mine (south shaft)	28-32 6-11	NW NW-NE-SW-SW Sec 6-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open and 15' in diameter at surface, thick vegetation near opening, hole is water-filled	Chat/ boulder piles in the vicinity could be used for back-filling purposes
Church & Company Mine (east shaft)	28-32-6-12	SE-SW-SE-NW-SW Sec 6-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open, 5' in diameter water-filled, thick vegetation near hole	All mining waste (chats, boulders, concrete) in area can be used for back filling

Table A-1 - OPEN MINE SHAFTS - Continued

Name	Site #	Location	Present Condition	Suggested Remedial Action
Center Creek Mining Company Mine (east workings-northeast shaft)	28-32-17-32	SE-SE-SE-NW-SW Sec 17-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open and water-filled to surface, 4' X 4' wood-cribbing is visible below water	Cyclone fencing and posting "DANGER" signs should provide reasonable safeguards
Center Creek Mining Company Mine (east workings-northwest shaft)	28-32-17-33	SW-SE-SE-NW-SW Sec 17-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open and water-filled to surface, 3' X 3' wood-cribbing is visible below water	Cyclone fencing and posting "DANGER" signs should provide reasonable safeguards
Ben Franklin Mine (south shaft)	28-32-17-36	SE-SW-NW-SW-SW Sec 17-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open 10' X 10' concrete collar is intact, 15' deep to trash fill	Back-fill materials are in the area, chain-link fencing and warning signs are also suggested
Ben Franklin Mine (north shaft)	28-32-17-38	E2-NW-NW SW-SW Sec 17-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open, 40' in diameter at surface, caving 20' down to water level, 8'-diameter pool, Mississippian bedrock exposed in shaft walls	All mining waste (chats boulders, concrete) in area can be used for back-filling
Sunset Mine (west workings-south shaft)	28-32-17-39	SE-NW-SE-NW-SW Sec 17-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open within chat pile 3' X 3' wood-cribbed hole is water-filled	Chat/boulder piles in the vicinity could be used for back-filling purposes
Sunset Mine (west workings-east shaft)	28-32-17-40	C-N2-SE-NW-SW Sec 17-28N -32W Webb City Quad Jasper Co , Mo	Shaft is open and producing an artesian flow, 20' in diameter at surface, sides are unstable	Back-filling recommended nearby chat/boulder piles can be used for fill material
Sunset Mine (west workings-central shaft)	28-32-17-41	NE-NW-SE-NW-SW Sec 17-28N 32W Webb City Quad Jasper Co Mo	Shaft is open within chat pile 10' in diameter at surface, hole is water-filled	All mining waste (chats boulders concrete) in area can be used for back-filling

Reference # 3

Census of Missouri Public Water Supplies 1982

Missouri Department of Natural Resources
Division of Environmental Quality
Public Drinking Water Program
May 1982

Reference #4

ATMOSPHERIC TRANSPORT OF LEAD FROM

MILL TAILINGS IN THE TRI-STATE DISTRICT

by

Guy Neenan

B A , University of Missouri, Columbia 1971

In partial fulfillment of the requirements for the degree of Master of Science in Environmental Health Science from the University of Kansas School of Engineering, Department of Civil Engineering, Division of Environmental Health

Presented November 11, 1982

Prepared with the supervision of Professors Dennis Lane, Carl Burkhead, and George Traiger

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skewed from pile to pile, and from different levels within the same pile Typically, coarser particles cover the surface 5 mm of a pile with finer particles underlying Piles are well drained in general and are not compressible Surface crusting, which would stabilize the piles from weathering does not occur

Perhaps the most important feature of chat material which makes it an interminable environmental nuisance is its zinc content Zinc is phytotoxic and vegetation is unable to establish a turf which would reduce wind and water erosion The problems of revegetation of chat material were discussed in a previous report (3) Conclusions from this report are listed in Table 2

1	Surfaces should be graded to slopes no greater than 16%
2	Surfaces should be neutralized with lime or sewage sludge to reduce pH and heavy metal transport
3	Surfaces should be assayed for pH, heavy metal concentrations, and grain sizes
4	Topsoil could be used only if a minimum of 45 cm depth is applied
5	Sewage sludge or locally derived industrial materials, even if inert, could be useful amendments
6	Less fertile amendments such as shale, clay, or carbonate-rich fill are superior to enriched amendments because they reduce root penetration depth
7	Native, shallow-rooting, and tolerant grass species are better choices for reseeding
8	There is a need for research about legume survival under high heavy metal stress
9	Boron addition would be critical for legume survival
10	Vegetation would require maintenance by reseeding and by nitrogen and phosphate fertilization
11	Vegetation would be unsuitable for livestock forage
12	Revegetation efforts would be economically feasible only at high priority sites, or for research-demonstration plots

Table 2 List of conclusions from study of lead-zinc tailings reclamation by revegetation Reference 3

Reference # 6

REPORT
GROUND WATER ASSESSMENT PLAN
VICKERS/JOPLIN

JOB NO 14117-001-17
FEBRUARY 5, 1985

Dames & Moore

Dames & Moore

An investigation of possible sources of the observed upgradient contamination indicates that in the past, waste oils may have been placed in a "sinkhole" near well 5 Although these activities were discontinued in the 1970s, it appears that only a partial cleanup of the area was accomplished A ground water assessment of the contamination area will now be discussed in Part 2 of this letter

GEOLOGIC DESCRIPTION

The waste management area is located in the Springfield Plateau physiographic region in Joplin, Missouri This area is underlain by approximately 350 feet of Mississippian age limestones which dip gently to the west The area forms part of the Tri-State lead and zinc district and has been extensively mined in the past Solutioning of the Mississippian limestones after deposition produced caves, solution channels, and characteristic karst structures within the limestones These openings, having inadequate roof support collapsed giving rise to brecciated zones composed of chert left behind as the limestone was dissolved Subsequent mineralization of the brecciated zones produced the ore deposits mined in the area

GROUND WATER FLOW

The aquifer within the Mississippian limestones is both a confined and water table aquifer determined by the location of the brecciated areas The karstic characteristics of the area have produced zones of highly permeable material (brecciated areas) and zones of very low permeability (undisturbed areas of dense limestone) Mining of the mineralized zones has produced caverns containing pools of ground water within the limestone Water table conditions are encountered where these brecciated zones have surface expression through sinkholes and mine shafts Where the lower permeability limestones overlie the brecciated zone the aquifer is commonly under confined conditions

Local ground water conditions as determined by the existing monitoring wells indicate that there is a large fluctuation in water levels with a range of 9 feet measured from October 1984 to January 1985 (Figure 3)

The present piezometric data from these wells indicate an east-northeast ground water flow direction which is consistent over the range of measured water levels (Figures 4 5, and 6)